VOLUME XV JULY, 1932 NUMBER 4

JOURNAL OF DAIRY SCIENCE

PUBLISHED BY THE
AMERICAN DAIRY SCIENCE ASSOCIATION

Contents

Calcium and Phosphorus Metabolism in Dairy Cows. V. The Relative Assimilation of Calcium from Grades 1 and 3 Timothy Hay. W. A. TURNER, E. A. KANE AND W. S. HALE 267

A Comparison Between Ground Soybeans and Linseed Oilmeal as Protein Supplements for Growing Dairy Calves. J. H. HILTON, J. W. WILBUR and S. M. HAUGE 277

The Effect of Cod Liver Oil in the Ration Upon the Quantity and Quality of Cow's Milk. W. E. PETERSEN 283

The Use of Skimmilk Powder in Grain Rations for Dairy Calves. M. H. BERRY 287

A Formula for Evaluating Feeds on the Basis of Digestible Nutrients. W. E. PETERSEN 298

The Relation of the Soluble Portion of Alfalfa to the Rapid Absorption of Feed Flavor in Milk. C. L. ROADHOUSE and J. L. HENDERSON 299

A Study of Methods Used in Conducting a Silage Feeding Experiment. A. D. PRATT 303

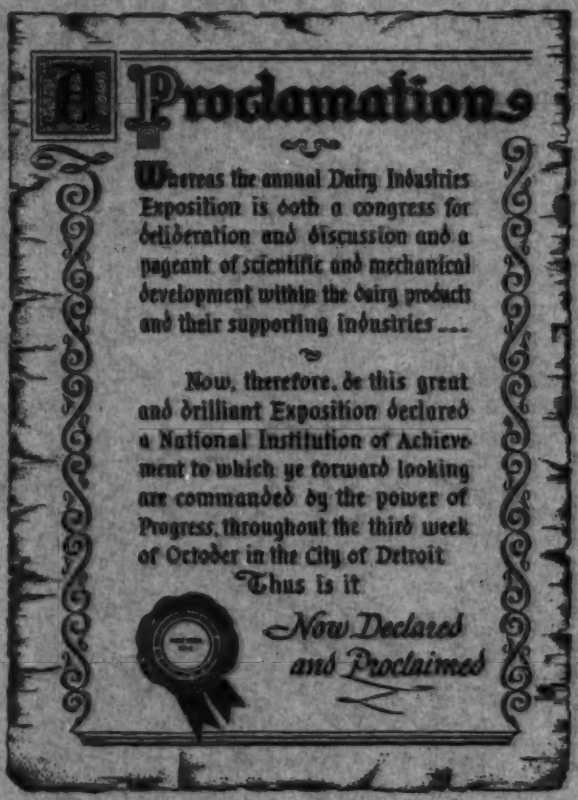
Method for Obtaining Representative Samples of Blood for Inorganic Phosphorus in Dairy Heifers. H. O. HENDERSON and A. H. VAN LANDINGHAM 313

The Coli-Aerogenes Determination in Pasteurization Control. M. H. MCGRADY and E. LANGEVIN 321

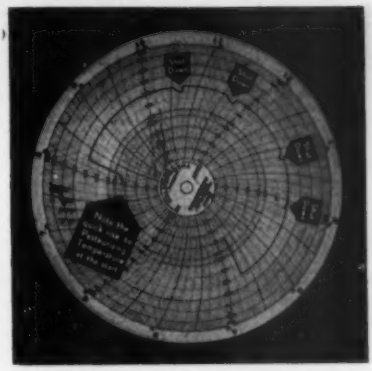
The Heat Coagulation of Milk. 1.—Variations in the Compositions, Heat Stability, and other Tests of Milk from Four Cows During the Course of a Lactation Period. G. E. HOLM, B. H. WEBB and E. F. DEYSHER 331

THE SCIENCE PRESS PRINTING COMPANY
LIME AND GREEN STREETS, LANCASTER, PA.

Made in United States of America


A Proclamation
Whereas the annual Dairy Industries Exposition is both a congress for deliberation and discussion and a pageant of scientific and mechanical development within the dairy products and their supporting industries ....
Now, therefore, be this great and brilliant Exposition declared a National Institution of Achievement to which ye forward looking are commanded by the power of Progress, throughout the third week of October in the City of Detroit
Thus is it
Now Declared and Proclaimed

Entered as second-class mail matter at Baltimore, Md., Post Office. Application for transfer to Lancaster, Pa., Post Office, pending.
Copyrighted, 1932, by the AMERICAN DAIRY SCIENCE ASSOCIATION.



POSITIVE CONTROL

in

PASTEURIZING MARKET MILK

The thermal recorder chart shown above is a typical record taken from a *Cherry-Burrell* Isotherm Heater now in daily operation in a recent large installation. Note the quick, positive rise to pasteurizing temperature at the start, and the evenness of the line showing how this temperature was maintained—within tenths of a degree. Also note the *immediate* return to pasteurizing temperature when the milk flow was resumed after a shutdown while awaiting milk from storage.

CHERRY-BURRELL
ISOTHERM MILK HEATER

Milk is delivered ***right at pasteurizing temperature*** direct to the holders by this remarkable heater, ***without danger of overheating or underheating.*** This contributes toward assuring a deep cream layer and natural flavor in the bottle.

Invisible hands, under automatic air-operated control (chosen by our engineers because of extreme accuracy) determine the steam needed and the hot water flows necessary to keep the milk exactly at pasteurizing temperature.

It is a two-stage heater of internal tube design, with a roughing heater and a final, finishing heater. Each heater section has its individual hot water storage tank and motor driven pump. Hot water is pumped in huge volume through each section at temperatures so low as to prove a barrier against overheating.

CHERRY-BURRELL
"SHORTIME" PASTEURIZER

During the past several months a demand has arisen for an apparatus for use as a high temperature, short time holding pasteurizer. The ***Cherry-Burrell*** Isotherm Heater, developed primarily for "batch" pasteurization, by a few simple changes becomes a ***Cherry-Burrell*** "Shortime" Pasteurizer. Write for information.

CHERRY-BURRELL CORPORATION
427 W. RANDOLPH ST.
CHICAGO

Your advertisement is being read in every State and in 25 Foreign Countries

AMERICAN DAIRY SCIENCE ASSOCIATION

INCORPORATED IN THE DISTRICT OF COLUMBIA

Officers

President ..... E. L. ANTHONY, East Lansing, Mich.
Vice-President ..... R. B. STOLTZ, Columbus, Ohio.
Secretary-Treasurer ..... R. R. GRAVES, Washington, D. C.
Editor ..... A. C. DAHLBERG, Geneva, N. Y.

Officers of Sections

SECTION NO. 1—Dairy Production

Chairman ..... G. BOHSTEDT, Madison, Wisconsin.
Secretary ..... T. W. GULLICKSON, St. Paul, Minnesota.

SECTION NO. 2—Dairy Manufacturers

Chairman ..... R. B. STOLTZ, Columbus, Ohio.
Secretary ..... E. G. HOOD, Ottawa, Canada.

SECTION NO. 3—Extension

Chairman ..... M. J. REGAN, Columbia, Missouri.
Vice-Chairman ..... M. L. FLACK, Lincoln, Nebraska.
Secretary ..... C. R. GEARHART, State College, Pa.

SECTION NO. 4—Dairy Economics

Chairman ..... F. A. BUECHEL, Austin, Texas.
Secretary ..... ROY C. POTTS, Washington, D. C.

Officers of Divisions

Southern ..... R. B. BECKER, Chairman, Gainesville, Fla.
R. H. LUSH, Secretary, Baton Rouge, La.

Eastern ..... A. L. BEAM, Chairman, State College, Pa.
C. B. BENDER, Secretary, New Brunswick, N. J.

Western ..... D. R. THEOPHILUS, Chairman, Moscow, Idaho.
R. W. MORSE, Secretary-Treasurer, Corvallis, Oregon.

The American Dairy Science Association was organized to advance the general welfare of the dairy industry, especially by the improvement of dairy instruction by the stimulation of scientific research in all phases of the subject and by improvement in methods of conducting extension work.

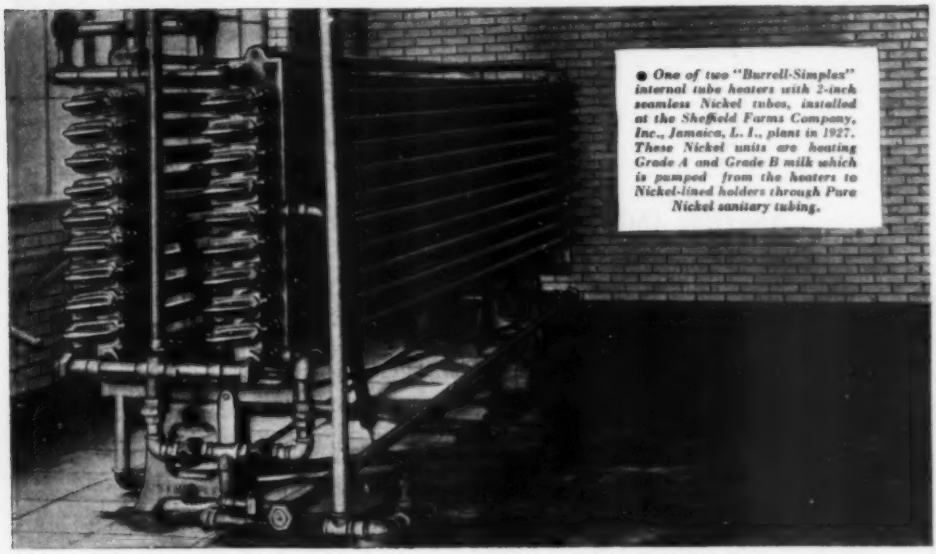
Membership shall consist of two kinds: (1) active, (2) associate.

The qualifications for membership in the two classes are as follows: (a) Any person is eligible to active membership who is formally announced by an Agricultural College, or Experiment Station, or by the Bureau of Dairying of the United States Department of Agriculture as an instructor, extension worker, investigator, or administrative officer connected with the dairy industry, or (b) anyone filling a position of responsibility connected with the dairy industry and who has had a college or University training in technical science, or anyone filling a responsible position in the industry of a professional character requiring a technical knowledge of dairying of a high order.

Any person is eligible to associate membership who is regularly enrolled in a collegiate course in a college of Agriculture and who is specializing in dairying. Associate membership is attained by election to membership in a local chapter of the American Dairy Science Association.

The dues are $5.00 a year for active membership. Correspondence regarding membership and dues should be addressed to R. R. Graves, United States Department of Agriculture, Washington, D. C.

Your advertisement is being read in every State and in 25 Foreign Countries



● *One of two "Burrell-Simplex" internal tube heaters with 2-inch seamless Nickel tubes, installed at the Sheffield Farms Company, Inc., Jamaica, L. I., plant in 1927. These Nickel units are heating Grade A and Grade B milk which is pumped from the heaters to Nickel-lined holders through Pure Nickel sanitary tubing.*

Dairy service records prove that pure NICKEL tubing "PROTECTS BETTER LONGER" in heating units

● Internal tubular heaters for pasteurizing sweet milk and cream furnish an excellent example of the superiority of Pure Solid Nickel dairy equipment. Here, where cleaning is difficult and the danger of corrosion and contamination consequently increased, the advantages of Pure Nickel seamless tubing become strikingly apparent.

Comparative service records over a period of years prove that Nickel is the most satisfactory and economical metal available in tubular form, for the construction of heaters.

Moreover, Nickel insures a wholesome product of low bacteria count because it is so easy to clean and keep clean. Owing to Nickel's non-porous, smooth surface, cleaning and flushing between batches is accomplished with minimum time and labor and maximum assurance of complete sanitation.

Users also find that Nickel construction gives storage, heating, holding and filling equipment great durability and long freedom from repairs and replacements. Nickel is rust-proof and strong as steel . . . and it has no coating to chip, crack or wear off. Nickel equipment installations made years ago still retain their original efficiency and attractiveness.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL STREET, NEW YORK, N. Y.

MACHINERY AND SUPPLIES ASSOCIATION

ASSOCIATE MEMBER

Ni NICKEL

Nickel
PROTECTS BETTER LONGER

Our Bulletin TS-1, "The Resistance of Nickel and Inco Chrome Nickel to Corrosion by Milk", contains valuable technical information which should be in your file for ready reference. Write for a copy.

Your advertisement is being read in every State and in 25 Foreign Countries

American Dairy Science Association Announcements

MEETING OF SOUTHERN SECTION

The southern section of the American Dairy Science Association held its annual meeting on February 3 and 4, 1932, in Birmingham, Alabama.

In his opening remarks, chairman Earl Weaver, of Oklahoma, called attention to the fact that the southern states contained 26 per cent of the total number of cows in the United States but they produced only 18 per cent of the total milk and the farmers receive only 10.7 per cent of the total cash paid for dairy products. He attributed this discrepancy to lack of proper feeding methods, poor training of dairy farmers and factory men, and variable quality of dairy products.

Various interesting subjects in dairy production and manufactures were discussed. G. Bohstedt, of Wisconsin, gave an address on the mineral feeding problem. Prof. J. C. Grimes, of Alabama, presented a paper on pastures. The committee on pastures for the southern section of which R. H. Lush, of Louisiana, is chairman reported on methods of evaluating dairy pastures. Upon motion of R. B. Becker, the southern section petitioned the agronomists to cooperate with their committee to develop methods of measuring results of pasture investigations. The problem of evaluation of pastures is important not only from a practical viewpoint but also in planning for and interpreting experimental work so that this activity of the southern section will be of special interest to the entire Association.

The nominating committee reported at the meeting and mail balloting resulted in the election of R. B. Becker, of Florida, as chairman, A. D. Burke, of Alabama, as vice chairman, and R. A. Lush, of Louisiana as secretary.

Your advertisement is being read in every State and in 25 Foreign Countries

CALCIUM AND PHOSPHORUS METABOLISM IN DAIRY COWS. V.—THE RELATIVE ASSIMILATION OF CALCIUM FROM GRADES 1 AND 3 TIMOTHY HAY

WILLIAM A. TURNER, EDWARD A. KANE, AND WALTER S. HALE

Bureau of Dairy Industry, U. S. Department of Agriculture, Beltsville, Maryland

INTRODUCTION

Differences in the assimilation by dairy cows of calcium from alfalfa hay cured by different procedures, were first shown by Hart and his collaborators in Wisconsin. They found that hay that had been "cured under caps" gave a better assimilation than that which had been "exposed in windrows to air and light for four days" (1, 2).

The fact that the calcium of well-cured alfalfa hay is better assimilated by dairy cows than that of poorly-cured alfalfa hay was demonstrated in work conducted at this station (3). Alfalfa was cut and, after a few hours' drying in the field, spread loosely over racks in an open shed where it was exposed to the air but to no sun or rain. Another lot of the same hay was left in the field for more than a week where it was exposed to the sun and to one and one-half days of rainy weather. When these hays were fed the retention of calcium from the weathered hay was 14–15 grams per day less than that from the hay cured under cover. Assuming that the lesser calcium retention with the alfalfa exposed to sun and rain was probably due to a vitamin D deficiency,[1] an attempt was made to remedy this by the administration of cod-liver oil for a period of three weeks. No improvement in calcium assimilation was noted. In fact there was a greater loss of calcium from the body when the cod-liver oil was fed.

The question as to the effect of curing on the quality of hay is one of considerable practical as well as scientific interest. It was therefore decided to investigate different grades of other hays and for this purpose grades 1 and 3 timothy hay were first chosen for comparison and a series of balance experiments initiated. In the first experiment, conducted during the winter months of 1929, conditions were not entirely satisfactory and the results were rather inconclusive. The experiment was, therefore, repeated with some variations in the spring of 1930.

EXPERIMENTAL

For the 1929 experiment two pure-bred Holstein cows were used. Cow 200, 10 years old, had calved three months previous to the experiment and

Received for publication September 2, 1931.

[1] Steenbock *et al* later showed with rats that clover hay exposed to the sun contained more Vitamin D than that which was not so exposed (4).

was giving 13 kgs. of milk daily. Cow 208, 5 years old, had calved two and one-half months previous to the experiment and was giving 8.5 kgs. of milk daily. Cow 200 maintained her weight through the experiment, while cow 208 gained 30 kgs. Both cows received timothy hay for eight months previous to the experiment, it being of No. 1 grade during the last month.

A ration of U. S. Grade 1 timothy hay and a grain mixture of corn meal, 30; linseed oil meal, 25; soy-bean meal, 25; wheat bran, 20; and salt, 1, was fed during the first four weeks of the experiment. During the next five weeks U. S. Grade 3 timothy hay, with the same grain mixture, was fed. The same ration was fed during the final three weeks of the experiment and a supplement of 50 grams per day of sodium citrate was included. A sup-

TABLE 1

Percentage composition of feeds

PERIOD	FEED	H_2O	Ca	P	N
Jan. 3–30	Timothy Hay, T 16 Grade 1	11.41	0.175	0.120	0.892
Jan. 31–Feb. 22	Timothy Hay, T 13 (1) Grade 3	10.80	0.240	0.103	0.656
Feb. 23–March 6	" " " (2)	10.57	0.235	0.101	0.644
March 7–27	" " " (3)	10.04	0.240	0.102	0.653
Jan. 3–15	Grain 65 M 1	11.74	0.686	0.620	4.00
Jan. 16–29	" 65 M 2	11.42	0.657	0.626	3.96
Jan. 30–Feb. 12	" 65 M 3	11.45	0.659	0.631	3.96
Feb. 13–28	" 65 M 4	11.78	0.774	0.777	3.90
March 1–6	" 65 M 5	12.56	0.687	0.758	4.04
March 7–23	" 65 M 6	11.70	0.747	0.783	3.98
March 24–27	" 65 M 7	12.01	0.739	0.711	3.87

TABLE 2

Percentage composition of milks

1929	COW 200			COW 208		
Week	Ca	P	N	Ca	P	N
Jan. 5–11	0.110	0.110	0.508	0.101	0.087	0.507
" 12–18	0.110	0.106	0.472	0.103	0.084	0.481
" 19–25	0.113	0.106	0.501	0.103	0.088	0.502
" 26–Feb. 1	0.111	0.108	0.502	0.099	0.089	0.507
Feb. 2–8	0.115	0.108	0.515	0.102	0.088	0.489
" 9–15	0.111	0.111	0.534	0.096	0.088	0.500
" 16–22	0.107	0.109	0.510	0.099	0.083	0.487
" 23–Mar. 1	0.108	0.110	0.521	0.095	0.087	0.495
Mar. 2–8	0.118	0.111	0.526	0.101	0.086	0.496
" 9–15	0.112	0.112	0.541	0.094	0.088	0.507
" 16–22	0.118	0.110	0.538	0.099	0.088	0.494
" 23–29	0.117	0.108	0.537	0.101	0.086	0.502

TABLE 3

Weekly calcium balances

Week	cow 200					cow 208				
	Ca in urine and feces	Ca in milk	Ca in feed	Ca balance	Milk yield	Ca in urine and feces	Ca in milk	Ca in feed	Ca balance	Milk yield
1929	*gm.*	*gm.*	*gm.*	*gm.*	*kg.*	*gm.*	*gm.*	*gm.*	*gm.*	*kg*
Grade 1 Timothy Hay + $CaCl_2$ and limestone										
Jan. 5–11	275.7	107.8	421.9	+ 38.4	98.0	314.0	61.0	421.9	+ 46.9	60.4
Jan. 12–18	281.7	102.5	395.9	+ 11.7	93.2	318.2	61.6	395.9	+ 16.1	59.8
Jan. 19–25	291.0	105.4	407.7	+ 11.3	93.3	309.1	63.7	407.7	+ 34.9	61.8
Jan. 26–Feb. 1	277.4	100.8	407.9	+ 29.7	90.8	302.7	54.9	407.9	+ 50.3	55.5
Average	281.5	104.1	408.4	+ 22.8	93.8	311.0	60.3	408.4	+ 37.1	59.4
Grade 3 Timothy Hay + $CaCl_2$ and limestone										
Feb. 2–8	323.4	101.3	423.7	− 1.0	88.1	330.3	57.5	440.5	+ 52.7	56.4
Feb. 9–15	297.1	100.0	435.8	+ 38.7	90.1	365.2	51.3	452.6	+ 36.1	53.4
Feb. 16–22	314.8	89.5	425.9	+ 21.6	83.6	316.5	51.6	442.7	+ 74.6	52.1
Feb. 23–Mar. 1	238.7	86.4	417.2	+ 92.1	80.0	303.7	47.7	440.8	+ 89.4	50.2
Mar. 2–8	257.4	93.8	374.3	+ 23.1	79.5	310.0	49.8	403.7	+ 43.9	49.3
Average	286.3	94.2	415.4	+ 34.9	84.3	325.1	51.6	436.1	+ 59.3	52.3
Grade 3 Timothy Hay + $CaCl_2$, limestone and sodium citrate										
Mar. 9–15	301.1	86.9	440.7	+ 52.7	77.6	312.8	45.4	457.5	+ 99.3	48.3
Mar. 16–22	296.6	95.1	452.4	+ 60.7	80.6	372.2	49.2	483.6	+ 62.2	49.7
Mar. 23–29	283.3	88.5	424.1	+ 52.3	75.6	383.4	51.6	481.1	+ 46.1	51.1
Average	293.7	90.2	439.1	+ 55.2	77.9	359.1	48.7	474.1	+ 69.2	49.7

TABLE 4

Weekly phosphorus balances

Week	COW 200					COW 208				
	P in urine and feces	P in milk	P in feed	P balance	Ca/P ratio	P in urine and feces	P in milk	P in feed	P balance	Ca/P ratio
1929	*gm.*	*gm.*	*gm.*	*gm.*		*gm.*	*gm.*	*gm.*	*gm.*	
Grade 1 Timothy Hay + $CaCl_2$ and limestone										
Jan. 5–11	225.1	107.8	362.6	+29.7	1.16	278.0	52.5	362.6	+32.1	1.16
Jan. 12–18	245.1	98.8	341.3	− 2.6	1.16	288.0	50.2	341.3	+ 3.1	1.16
Jan. 19–25	256.5	98.9	365.5	+10.1	1.11	269.0	54.4	365.5	+42.1	1.11
Jan. 26–Feb. 1	268.0	98.1	366.1	0.0	1.11	313.8	49.4	366.1	+ 2.9	1.11
Average	248.7	100.9	358.9	+ 9.3	1.14	287.2	51.6	358.9	+20.1	1.14
Grade 3 Timothy Hay + $CaCl_2$ and limestone										
Feb. 2–8	249.2	95.1	352.5	+ 8.2	1.20	285.4	49.6	359.7	+24.7	1.22
Feb. 9–15	279.3	100.0	368.0	−11.3	1.18	340.4	47.0	375.2	−12.2	1.21
Feb. 16–22	297.5	91.1	369.6	−19.0	1.15	340.8	43.2	376.8	− 7.2	1.17
Feb. 23–Mar. 1	289.0	88.0	365.9	−11.1	1.14	327.1	43.7	376.0	+ 5.2	1.17
Mar. 2–8	305.0	88.2	373.1	−20.1	1.00	367.1	42.4	385.7	−23.8	1.05
Average	284.0	92.5	365.8	−10.7	1.13	332.2	45.2	374.7	− 2.7	1.16
Grade 3 Timothy Hay + $CaCl_2$, limestone and sodium citrate										
Mar. 9–15	304.0	86.9	399.1	+ 8.2	1.11	346.9	42.5	406.3	+16.9	1.13
Mar. 16–22	311.4	88.7	420.4	+20.3	1.07	372.2	43.7	433.7	+17.8	1.11
Mar. 23–29	280.0	81.6	372.8	+11.2	1.14	356.2	43.9	411.0	+10.9	1.17
Average	298.5	85.7	397.4	+13.2	1.11	358.4	43.4	417.0	+15.2	1.14

TABLE 5

Percentage composition of feeds

PERIOD	FEED	H_2O	Ca	P	N
March 13–April 7	Timothy Hay, T 22 (1) Grade 3	7.83	0.393	0.124	0.694
April 8–May 9	" " " (2)	11.27	0.367	0.129	0.611
May 10–June 4	" " " (3)	10.76	0.391	0.126	0.594
June 5–27	Timothy Hay, T 21 Grade 1	8.70	0.397	0.114	0.971
March 13–20	Grain 65 M 1	10.95	0.616	0.668	3.90
" 21–29	" 65 M 2	10.87	0.730	0.736	4.10
" 30–April 2	" 65 M 3	10.91	0.729	0.723	4.10
April 3–11	" 65 M 4	10.92	0.657	0.718	4.17
" 12–20	" 65 M 5	12.00	0.619	0.724	4.06
" 21–23	" 65 M 6	10.90	0.634	0.743	4.10
" 24–May 3	" 65 M 7	10.99	0.735	0.741	4.11
May 4–11	" 65 M 8	9.96	0.738	0.736	4.10
" 12–14	" 65 M 9	10.60	0.754	0.758	4.23
" 15–25	" 65–1	10.41	0.233	0.777	4.29
" 26–June 3	" 65–2	10.73	0.206	0.722	4.16
June 4–13	" 65–3	10.46	0.210	0.732	4.41
" 14–23	" 65–4	11.93	0.190	0.707	4.32
" 24–27	" 65–5	9.71	0.215	0.697	4.29

TABLE 6

Percentage composition of milks

1930	cow 266			cow 270		
Week	Ca	P	N	Ca	P	N
March 15–21	0.106	0.096	0.481	0.121	0.106	0.508
" 22–28	0.111	0.099	0.523	0.115	0.107	0.529
" 29–April 4	0.110	0.096	0.519	0.119	0.106	0.527
April 5–11	0.110	0.097	0.564	0.119	0.107	0.535
		cow 105				
" 12–18	0.098	0.095	0.481	0.118	0.108	0.533
" 19–25	0.104	0.099	0.497	0.128	0.108	0.538
" 26–May 2	0.097	0.097	0.497	0.118	0.104	0.528
May 3–9	0.099	0.091	0.482	0.123	0.106	0.522
" 10–16	0.098	0.094	0.490	0.115	0.110	0.531
" 17–23	0.096	0.095	0.496	0.119	0.111	0.546
" 24–30	0.102	0.098	0.514	0.124	0.112	0.539
" 31–June 6	0.102	0.095	0.513	0.118	0.107	0.539
June 7–13	0.102	0.099	0.515	0.116	0.111	0.547
" 14–20	0.107	0.098	0.513	0.123	0.108	0.544
" 21–27	0.105	0.101	0.524	0.128	0.108	0.546

TABLE 7

Weekly calcium balances

Week	cow 266					cow 270				
	Ca in urine and feces	Ca in milk	Ca in feed	Ca balance	Milk yield	Ca in urine and feces	Ca in milk	Ca in feed	Ca balance	Milk yield
1930	*gm.*	*gm.*	*gm.*	*gm.*	*kg.*	*gm.*	*gm.*	*gm.*	*gm.*	*kg.*
Grade 3 timothy hay + $CaCl_2$, limestone and sodium citrate										
Mar. 15–21	575.0	188.2	755.3	− 7.9	177.5	685.1	261.2	847.5	− 98.8	215.9
Mar. 22–28	657.8	196.1	755.1	− 98.8	176.7	720.6	247.9	929.6	− 38.9	215.6
Mar. 29–Apr. 4	660.5	165.2	766.1	− 59.6	150.2	747.0	253.0	942.8	− 57.2	212.6
Average	631.1	183.2	758.8	− 55.4	168.1	717.6	254.0	906.6	− 65.0	214.7
Grade 3 timothy hay + $CaCl_2$ and limestone										
Apr. 5–11	453.6*	116.3*	511.2*	− 58.7*	105.7*	680.4	257.9	875.8	− 62.5	216.7
	cow 105									
Apr. 12–18	481.0	144.3	573.4	− 51.9	147.2	600.2	253.1	837.4	− 15.9	214.5
Apr. 19–25	470.8	153.5	573.8	− 50.5	147.6	672.4	273.9	833.7	− 112.6	214.0
Average	475.9**	148.9**	573.6**	− 51.2**	147.4**	651.0	261.6	849.0	− 63.7	215.1
Grade 3 timothy hay + limestone										
Apr. 26–May 2	540.5	145.7	642.9	− 43.3	150.2	741.5	251.5	925.7	− 67.3	213.1
May 3–9	517.2	149.1	644.1	− 22.2	150.6	735.7	258.8	927.3	− 67.2	210.4
May 10–16	528.8	143.7	657.5	− 15.0	146.6	722.4	240.2	948.4	− 14.2	208.9
Average	528.8	146.2	648.2	− 26.8	149.1	733.2	250.2	933.8	− 49.6	210.8
Grade 3 timothy hay										
May 17–23	294.7	139.6	350.1	− 84.2	145.4	380.1	241.7	524.1	− 97.7	203.1
May 24–30	321.3	141.8	358.5	− 104.6	139.0	342.4	257.3	514.4	− 85.3	207.5
May 31–June 6	267.5	141.1	349.1	− 59.5	138.3	339.7	235.2	501.9	− 73.0	199.3
Average	294.5	140.8	352.6	− 82.8	140.9	354.1	244.7	513.5	− 85.3	203.3
Grade 1 timothy hay										
June 7–13	251.0	148.0	354.6	− 44.4	145.1	313.9	235.5	509.9	− 39.5	203.0
June 14–20	247.9	153.1	344.7	− 56.3	143.1	334.1	248.2	496.7	− 85.6	201.8
June 21–27	273.3	151.3	347.6	− 77.0	144.1	316.9	262.4	500.6	− 78.7	205.0
Average	257.4	150.8	349.0	− 59.2	144.1	321.6	248.7	502.4	− 67.9	203.3

* 5 days. ** For cow 105 only.

TABLE 8
Weekly phosphorus balances

Week	cow 266					cow 270				
	P in urine and feces	P in milk	P in feed	P balance	Ca/P ratio	P in urine and feces	P in milk	P in feed	P balance	Ca/P ratio
1930	*gm.*	*gm.*	*gm.*	*gm.*		*gm.*	*gm.*	*gm.*	*gm.*	
Grade 3 timothy hay + $CaCl_2$, limestone and sodium citrate										
Mar. 15–21	430.0	170.4	603.1	+ 2.7	1.25	451.3	227.8	665.3	− 13.8	1.27
Mar. 22–28	438.5	174.9	589.0	− 24.4	1.28	484.1	229.6	714.3	+ 0.6	1.30
Mar. 29–Apr. 4	469.5	144.2	590.6	− 23.1	1.30	503.5	225.4	716.2	− 12.7	1.32
Average	446.0	163.2	594.2	− 14.9	1.28	479.6	227.6	698.6	− 8.6	1.30
Grade 3 timothy hay + $CaCl_2$ and limestone										
Apr. 5–11	314.0*	102.5*	416.7*	+ 0.2*	1.23*	517.3	231.9	708.5	− 40.7	1.24
cow 105										
Apr. 12–18	385.6	139.8	509.8	− 15.6	1.12	485.6	230.6	715.1	− 1.1	1.17
Apr. 19–25	429.1	146.1	524.5	− 50.7	1.09	530.3	231.1	723.4	− 38.0	1.15
Average	407.4**	143.0**	517.2**	− 33.1**	1.11**	511.1	231.2	715.7	− 26.6	1.19
Grade 3 timothy hay + limestone										
Apr. 26–May 2	399.2	145.7	530.0	− 14.9	1.21	524.8	221.6	730.8	− 15.6	1.27
May 3–9	357.8	137.0	528.0	+ 33.2	1.22	477.4	223.0	728.1	− 27.7	1.27
May 10–16	388.5	137.8	531.8	+ 5.5	1.24	483.5	228.7	732.8	+ 20.6	1.29
Average	381.8	140.2	529.9	+ 7.9	1.22	495.2	224.4	730.6	− 7.6	1.28
Grade 3 timothy hay										
May 17–23	422.6	138.1	555.0	− 5.7	0.63	559.3	225.4	758.5	− 26.2	0.69
May 24–30	438.1	132.0	570.1	− 24.8	0.63	516.3	232.4	738.7	− 10.0	0.70
May 31–June 6	419.8	131.4	526.4	− 24.8	0.66	520.5	213.3	713.5	− 20.3	0.70
Average	426.8	133.8	550.5	− 18.4	0.64	532.0	223.7	736.9	− 18.8	0.70
Grade 1 timothy hay										
June 7–13	419.8	143.7	525.0	− 38.5	0.68	504.5	225.3	710.7	− 19.1	0.72
June 14–20	383.8	140.2	512.6	− 11.4	0.67	490.0	217.9	694.2	− 13.7	0.71
June 21–27	403.7	145.5	507.0	− 42.2	0.69	463.6	221.4	686.7	+ 1.7	0.73
Average	402.4	143.1	514.9	− 30.7	0.68	486.0	221.5	697.2	− 10.4	0.72

* 5 days. ** For cow 105 only.

plement of calcium chloride and limestone was fed throughout the experiment in such amount as to maintain a Ca/P ratio of 1.0–1.2. The supplements were mixed with the grain, and hay and grain were fed twice daily. The cows were milked twice daily. Cow 200 was underfed (75% of Savage Standard) during three months following calving and cow 208 during one month following calving (89% of Savage Standard). Both cows received more than their energy requirements during the experiment (5–46% excess). They were not bred.

Table 1 shows the percentage composition of the feeds used and table 2 that of the milks. Tables 3 and 4 give the calcium and phosphorus balance data.

The experiment of the spring of 1930 was started with two pure-bred Holsteins, cows 266 and 270, of about 9 years of age. Both cows were in their third month of lactation and were giving 25–30 kgs. of milk daily. Previous to the experiment they were receiving alfalfa hay, corn silage and grain, but three days previous to the experiment the ration was changed to grade 3 timothy hay and grain with a supplement of calcium chloride, limestone and sodium citrate. This was fed for three weeks, then for the following three weeks the sodium citrate was omitted. For the next three weeks both sodium citrate and calcium chloride were omitted and during the fourth three weeks no supplement was given. During the fifth and final three weeks, grade 1 timothy hay and grain without supplement were fed.

During the fourth week of the experiment it became evident that cow 266, due to lameness, was unsuitable for the experiment. She was, therefore, discarded and a three year old grade Holstein, Cow 105, already receiving a timothy hay ration, was substituted. This cow was likewise in her third month of lactation. Cow 266 lost a little weight while on the experiment, but cows 105 and 270 both gained in weight. Hay and grain were fed twice daily and the cows were milked three times a day. Cows 105 and 266 were not bred but cow 270 was bred and was pregnant during the last month of the experiment.

Table 5 shows the percentage composition of the feeds used and table 6 that of the milks. Tables 7 and 8 give the calcium and phosphorus balance data.

DISCUSSION

The differentiation in the effect of different grades of timothy hay on the calcium and phosphorus assimilation is rather difficult and demonstrable only under the most favorable conditions. These conditions should include the use of as many animals as possible with high milk production so that the demand for minerals is acute.

In the 1929 experiment only two animals with rather low milk yields were available. In planning this experiment it was thought desirable to

add a calcium supplement to overcome the low calcium intake and Ca/P ratio on a timothy hay ration and thereby eliminate those factors in estimating the relative value of the hays. The calcium balances were somewhat better with the grade 3 hay. This improvement in calcium balances with the grade 3 hay may be more than accounted for by the increased calcium intakes and the decreased milk yields at the time this hay was fed. Unfortunately the grade 3 hay had a higher calcium content than did grade 1.

Sodium citrate was introduced into the ration with the thought that an acid radicle which predominates in alfalfa (5) and which is capable of holding calcium in solution might be an aid to calcium assimilation. The improvement in balances noted, however, when the sodium citrate was fed, can be more than accounted for by increased calcium intakes and decreased milk yields.

With sufficient calcium intakes and low milk yields the calcium balances in this experiment are all positive.

The experiment of 1930 was planned somewhat differently. Two cows with considerably higher milk yields were used. A comparison of grades 1 and 3 timothy hay without any mineral supplement was made. Grade 3 hay with all the supplements was fed first, then one supplement at a time was removed until the grade 3 hay alone with grain was fed. After that the grade 1 hay was substituted.

The balances when the different supplements were used are probably not very significant. One cow had to be removed from the experiment and another substituted in her place. The balances are shown to be somewhat better after the calcium chloride and sodium citrate had been removed and only the limestone supplement was given. The intakes of calcium and phosphorus, however, were greater during the latter period.

When all supplements were removed the balances became strongly negative due to the decreased calcium intakes.

The comparison of grades 1 and 3 timothy hay is marked and probably of some significance. The calcium balances were distinctly better on the grade 1 hay. In this comparison there was little change in calcium intakes or in milk yields and the cows were giving considerable amounts of milk. There was a considerable reduction in the excretion of calcium in the feces when the grade 1 hay was fed.

All the balances in this experiment were negative due to the high milk yields and probably insufficient mineral intakes.

CONCLUSIONS

These experiments seem to indicate that the ingestion of sodium citrate has little effect on calcium and phosphorus metabolism.

Grade 1 timothy hay seems to exert a more favorable effect than does grade 3 timothy hay on calcium assimilation in heavily milking cows.

REFERENCES

(1) HART, E. B., STEENBOCK, H., and HOPPERT, C. A. Jour. Biol. Chem. **53**: 21. 1922.
(2) HART, E. B., STEENBOCK, H., HOPPERT, C. A., BETHKE, R. M., and HUMPHREY, G. C. Jour. Biol. Chem. **54**: 75. 1922.
(3) MEIGS, E. B., TURNER, W. A., HARDING, T. S., HARTMAN, A. M., and GRANT, F. M. Jour. Agr. Research **32**: 861. 1926.
(4) STEENBOCK, H., HART, E. B., ELVEHJEM, C. A., and KLETZIEN, S. W. F. Jour. Biol. Chem. **66**: 425. 1925.
(5) TURNER, W. A., and HARTMAN, A. M. Jour. Am. Chem. Soc. **47**: 2044. 1925.

A COMPARISON BETWEEN GROUND SOYBEANS AND LINSEED OILMEAL AS PROTEIN SUPPLEMENTS FOR GROWING DAIRY CALVES

J. H. HILTON, J. W. WILBUR AND S. M. HAUGE

Departments of Dairy Husbandry and Research Chemistry, Purdue University Agricultural Experiment Station, Lafayette, Indiana

Experience has demonstrated that grain rations for farm animals in most instances should be supplemented with an adequate source of protein to give satisfactory and economical growth and production. Since most protein supplements are expensive, dairymen are becoming more and more interested in home grown protein feeds for dairy cattle. Such a source of protein is soybeans. Due to their high protein content, their yielding qualities and ability to grow on various types of soils, soybeans have attracted the attention of investigators and feeders as a source of protein supplement to the rations of different farm animals during various periods of development and production.

Numerous investigators (1, 2, 3, 4, 5) have found ground soybeans to be equal to linseed oilmeal as a protein supplement in the grain ration for milking cows. Likewise, experiments have shown that soybeans give satisfactory results for fattening hogs (6) and also for laying pullets (7). However, with young growing hogs and chicks, soybeans have not proven satisfactory as a protein supplement. Robinson (8) found that soybeans were not a satisfactory supplement to corn for weaning pigs which did not have access to forage and similar results were observed at Purdue (9). Experiments (10) with growing chicks indicated that optimum growth could not be secured with ground soybeans.

To the knowledge of the authors there have been no experimental results published on the value of ground soybeans as a protein supplement for growing dairy calves.

Since soybeans have become one of the chief sources of home grown proteins and due to the fact that most experimental work in studying soybeans as a feed for dairy cattle has been done with cows for milk production, it was decided to conduct some feeding trials for the purpose of determining the value of soybeans as a feed for growing dairy calves. Since linseed oilmeal has proven to be a satisfactory supplement to the grain ration of growing calves, it was decided to compare ground raw soybeans with linseed oilmeal as a standard in these trials.

Received for publication October 30, 1931.

Published with the approval of the Director of the Purdue University Agricultural Experiment Station.

EXPERIMENTAL PROCEDURE

Two trials have been completed in which eight calves have been raised on ground raw soybeans as a protein supplement, and eight calves on linseed oilmeal as a protein supplement. The first trial began in May 1929 and was continued for a period of 360 days. The second trial began in September 1930 and continued for a period of 330 days. Eight calves, divided into two groups of four calves each were used in each trial. In the first trial each group contained two Ayrshires, one Holstein and one Jersey whose average age at the beginning was 64 days. The groups in the second trial contained two Ayrshires and two Holsteins each, whose average age at the beginning of trial was 89 days. The groups were made as uniform as possible in regard to age, size and weight.

The calves received whole milk to 90 days of age when milk feeding was discontinued for the reason that the milk might mask the true biological value of the linseed oilmeal and the ground soybeans as protein supplements to the grain rations. The milk was fed at the rate of one pound of milk for each ten pounds of live weight of the calf with a maximum amount of ten pounds of milk per calf per day.

One group of calves received a grain ration containing linseed oilmeal, and the other group received ground soybeans. On the basis of chemical analyses of the individual feeds used in the grain mixture, the rations were formulated so as to furnish approximately the same percentage of total protein and total digestible nutrients. Periodic analyses of the grain mixtures showed them to contain practically the same amounts of protein. The average protein content of the linseed oilmeal ration was 16.20 per cent and of the soybean ration 16.35 per cent. The composition of the two grain mixtures is given in table 1.

In the first trial both groups of calves received timothy hay for the first ninety days and then were fed alfalfa hay during the remainder of the trial. In the second trial the calves were fed alfalfa hay during the entire trial.

TABLE 1

Kinds and amounts of ingredients in the grain mixtures

	LINSEED OILMEAL RATION	GROUND SOYBEAN RATION
	Lbs.	Lbs.
Ground Corn	300	318
Ground Oats	300	350
Wheat Bran	300	300
Linseed Oilmeal	200	.....
Ground Raw Soybeans	.....	182
Salt	10	10

The calves consumed sufficient amounts of hay and grain to keep them in good growing condition. They were fed twice daily and accurate records kept of the feeds consumed by each calf. The calves were fed in dry lot and did not have access to pasture at any time during the experiment.

The calves were weighed at the beginning of the experiment and every ten days thereafter, weights being taken for three successive days and an average of the three weights used as the true weight of the individual at that time. Their heights at withers were taken at the beginning of the trial and from then on every thirty days. Careful observations were made for digestive disorders, and any other abnormal conditions of the individual calves used in these trials. A summary of the results of the two feeding trials is given in table 2 and the gain in weight per 30 day interval is given in Chart I.

TABLE 2

Feeds consumed, gains made in weight and height by the calves on the experiment

	TRIAL I 1929–30		TRIAL II 1930–31		AVERAGE TWO TRIALS	
	Linseed Oilmeal	Ground Soybeans	Linseed Oilmeal	Ground Soybeans	Linseed Oilmeal	Ground Soybeans
No. calves	4	4	4	4	4	4
Ave. age at beginning—days	64	64	89	91	76.5	77.5
No. experimental days	360	360	330	330	345	345
Milk—lbs.	1225.0	1081.5	526.50	743.50	875.75	912.50
Grain—lbs.	6092.5	5953.75	5805.50	5730.00	5949.1	5841.9
Hay—timothy—lbs.	632.25	599.50	—	—	—	—
Hay—alfalfa—lbs.	4857.00	4857.00	6080.5	6080.5	—	—
Total hay—lbs.	5489.25	5456.50	6080.00	6080.5	5785.6	5768.50
Total dry matter—lbs.	10660.4	10486.7	10879.3	10827.5	10769.85	10657.1
Total gain wt.—lbs.	1701	1637	1805	1865	1753	1751
Ave. daily gain—lbs.	1.18	1.14	1.36	1.41	1.27	1.27
Lbs. dry matter per 1 lb. gain	6.27	6.41	6.02	5.81	6.14	6.09
Total increase height (inches)	54.2	53.1	52.4	53.6	53.3	53.35
Ave. monthly increase in height (inches)	1.129	1.108	1.191	1.218	1.158	1.159

DISCUSSION

A study of the data in table 2 shows that the average daily gain and the average monthly gain in height at withers of the calves on the two feeds was approximately the same.

Although there was a difference between the average daily gain in trials 1 and 2, the significant fact about these gains is that within each trial the

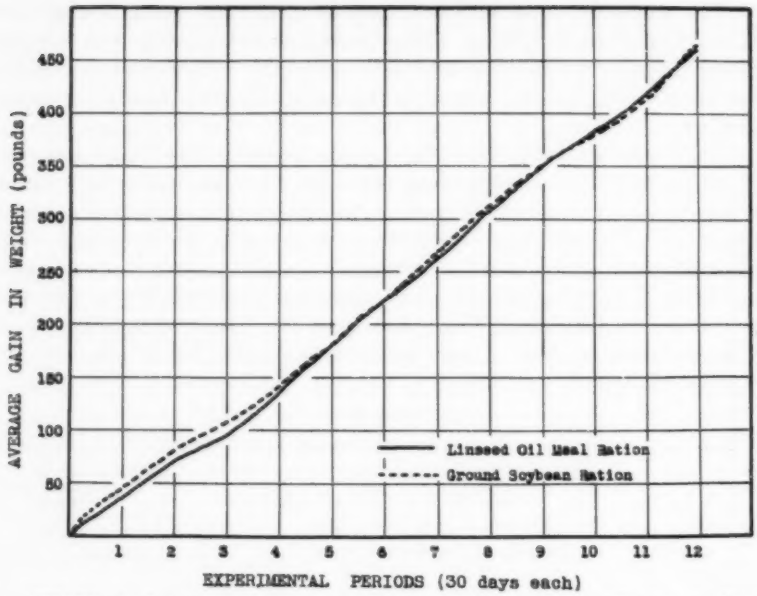


CHART I—Showing the Average Gain in Weight of the Calves of Each Group During the Two Trials Comparing Ground Soybeans and Linseed Oilmeal as Protein Supplements in the Grain Ration.

respective groups responded almost identically to the two rations. In fact it is readily seen that the values for the various measurements of response between feed mixtures in each trial are well within the limits of experimental error. Furthermore, the similarity of response of the two groups through each period of the feeding trial is clearly shown in Chart I.

Contrary to the results obtained with hogs (7) and chicks (8), these experiments showed that soybeans can be utilized as protein supplements by calves to make satisfactory growth. All the animals in these trials maintained good health and showed no physiological disorders as evidenced by general appearance, growth and the fact that all heifers used in the first trial have passed through normal reproductive cycles.

SUMMARY

1. Two trials, 360 days and 330 days respectively, have been completed in which eight calves have been raised on alfalfa hay and a grain ration containing linseed oilmeal, and eight calves on a comparable ration in which ground raw soybeans were used in place of linseed oilmeal as a protein supplement.

2. Ground raw soybeans and linseed oilmeal were found to be equally effective as protein supplements in the grain rations for growing heifer calves when fed with alfalfa hay.

REFERENCES

(1) McClandish, A. C., Weaver, Earl, and Lunde, L. A.: Soybeans as a homegrown supplement for dairy cows. Iowa Agri. Exp. Sta., Bulletin 204. 1922.

(2) Fairchild, L. H., and Wilbur, J. W.: Soybean oilmeal and ground soybeans as protein supplements in the dairy ration. Purdue Univ. Agri. Exp. Sta., Bulletin 289. 1924.

(3) Olson, T. M.: Soybeans for dairy cows. South Dakota Agri. Exp. Sta., Bulletin 213. 1925.

(4) Schaefer, O. G.: Soybeans and soybean hay in the dairy ration. Minnesota Agri. Exp. Sta., Bulletin 239. 1927.

(5) Hayden, C. C., and Perkins, A. E.: Soybeans and soybean oilmeal for milk production. Ohio Agri. Exp. Sta., Bi-Monthly Bulletin, **11**: No. 4, p. 137–141. July, 1926.

(6) Soybeans and mineral for fattening hogs. Thirty-Sixth Annual Report, Purdue Univ. Agri. Exp. Sta., p. 11. 1923.

(7) Philips, A. G., and Hauge, S. M.: Soybean oilmeal in rations for laying pullets. Purdue Univ. Agri. Exp. Sta., Bulletin 293. 1925.

(8) Robinson, W. L.: Soybeans and soybean oilmeal for pigs. Ohio Agri. Exp. Sta., Bulletin 452. 1930.

(9) Soybeans not an adequate supplement for fall pigs. Forty-first Annual Report, Purdue Univ. Agri. Exp. Sta., p. 34. 1928.

THE EFFECT OF COD LIVER OIL IN THE RATION UPON THE QUANTITY AND QUALITY OF COW'S MILK[1]

W. E. PETERSEN

Division of Dairy Husbandry, University of Minnesota, St. Paul, Minnesota

Until recently it has been generally believed that food exerted no marked influence upon the amount of fat in cows' milk. In recent years, however, this concept has been modified. This station, as well as others, have shown that certain food fats temporarily increased the fat content of milk. More recently there has appeared in the literature evidences that cod liver oil, menhaden oil, and safflower meal in the cows' ration has a depressing influence on the fat percentage of milk.

THE LITERATURE

Channon *et al.* (3) observed a tendency toward a decline in the fat content of cows' milk when cod liver oil was fed. This experiment was again reported by Drummond *et al.* (4) with comment to the effect that from the limited data (on three cows) they could not draw definite conclusions. From Reading, Golding and Zilva (5) and Mattick (7) reported that cod liver oil in the ration of milking cows had a depressing influence upon the fat content of the milk. Others have stated, without producing data, that cod liver oil in the ration depresses the fat content of the milk produced.

Harvey (6) found no effect on the fat content of goats' milk by feeding cod liver oil. This, coupled with the fact that the author found no depression of fat with two cows fed cod liver oil two years ago, suggested that further study of this problem was necessary.

In this connection, it is also of interest to note that Bünger (2) reports safflower meal as depressing the fat percentage of cows' milk up to 24 per cent, and Brown and Sutton (1) that menhaden (fish) oil acts similarly.

EXPERIMENTAL

The experimental animals—Twelve cows represented by Guernsey, Holstein, and Jersey breeds, and in different stages of lactation were selected. They were divided into two groups as nearly alike as possible as to breed and stage of lactation.

Feeding—The cows were fed the regular dairy herd ration consisting of alfalfa hay and corn silage for roughage while in the barn, and mixed

Received for publication October 31, 1931.

[1] Published with the approval of the Director as paper No. 1052, Journal Series, Minnesota Agricultural Experiment Station.

pasture grasses, chiefly blue grass, when on pasture. A grain mixture of corn 1 part, barley 1 part, oats 2 parts, and cottonseed meal ½ part was fed according to production. This is hereinafter known as the basal ration. For the experimental ration, five ounces of high grade biologically tested cod liver oil was added to the basal ration daily. It was added to the grain mixture at feeding time. No difficulty was experienced in getting the cows to eat the mixture.

Plan—The experiment was divided into three periods of 15, 23, and 20 days' duration. The first served as a preliminary period, and both groups received the basal ration only. During the second period, Group I had the basal ration only, and Group II received in addition five ounces cod liver oil daily. In the third group, Group I received the oil, and Group II the basal ration only.

Testing and records—Each milking was weighed, sampled, and examined for fat content by the Babcock method. The daily milk, fat, and fat percentage records were computed for each individual and for groups by periods.

TABLE 1

The fat percentage and average daily milk production for individual cows by periods. The marked lowering of fat percentage during cod-liver oil periods is to be noted

COW NUMBER	PERIOD I		PERIOD II		DIFFERENCE PERIOD II AND I	PERIOD III		DIFFERENCE PERIOD III AND II
	FAT	MILK	FAT	MILK	FAT	FAT	MILK	FAT
	per cent	*pounds*	*per cent*	*pounds*	*per cent*	*per cent*	*pounds*	*per cent*
	Preliminary		*Basal ration*			*Cod-liver oil*		
165	4.59	38.4	4.71	35.7	+ .12	4.60	33.8	− .11
173	5.36	32.1	5.12	33.9	− .24	3.93	31.5	− 1.19
383	3.95	49.7	3.33	55.0	− .62	2.46	51.0	− .87
393	3.33	67.1	3.03	64.7	− .30	2.51	61.7	− .52
402	3.61	60.1	3.20	65.7	− .41	2.13	63.1	− 1.07
540	4.53	24.7	4.31	27.0	− .23	3.55	26.1	− .76
Average					− .30			− .75
	Preliminary		*Cod-liver oil*			*Basal ration*		
171	4.77	34.3	4.12	32.9	− .65	4.31	26.9	+ .19
390	3.54	60.4	2.81	51.9	− .73	2.84	53.2	+ .03
396	3.94	58.5	2.84	66.9	− 1.10	2.85	64.7	+ .01
542	4.54	22.6	3.91	24.9	− .63	4.20	24.8	+ .29
549	5.97	21.2	5.34	20.1	− .63	5.93	20.6	+ .59
551	6.01	17.1	4.98	19.5	− 1.03	5.26	19.8	+ .28
Average					− .63			+ .232

DISCUSSION OF RESULTS

In table 1 are given the tabulated results of the experiment. In Period II (when Group I received only the basal ration and Group II the basal ration plus cod liver oil) the average fat percentage declined for both groups. The decrease is much greater, however, for Group II than for Group I being 0.815 per cent and 0.313 per cent, respectively. For this period all cows in Group II declined in fat percentage from 0.63 per cent to 1.10 per cent, while in Group I one cow showed an increase in fat percentage, and the maximum decrease was 0.62 per cent or less than the minimum for Group II.

In Period III, when Group I received the cod liver oil ration, the fat percentage of the milk declined for every cow with an average actual decline of 0.772 per cent as compared with the preceding period. Cod liver oil was withdrawn from the ration of Group II, and an increase in the fat percentage of the milk is noted for each cow.

In figure 1, the daily average fat percentage for each group is presented

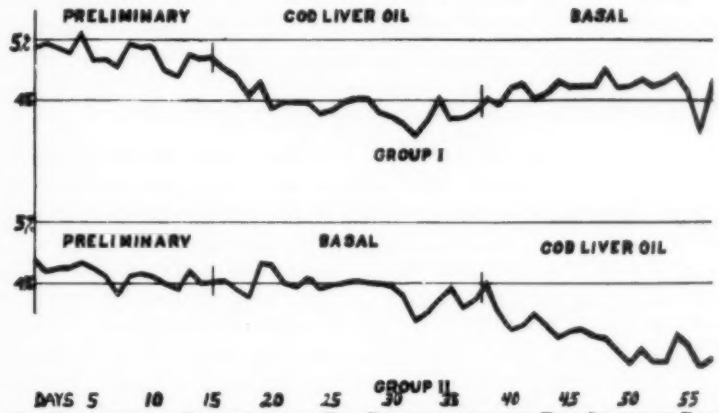


FIG. 1. COMPARISON OF DAILY AVERAGE FAT PERCENTAGE OF THE TWO GROUPS BY PERIODS. DOWNWARD TRENDS OF THE CURVE ARE NOTED WHEN COD-LIVER OIL IS INTRODUCED, AND SLOW RECOVERY TO NORMAL WHEN THE COD-LIVER OIL IS REMOVED

graphically. It will be noticed that the depression in fat percentage begins immediately after introducing cod liver oil into the ration, and also that cod liver oil has a cumulative effect in that it continues to depress that fat content of milk. For Group I the tendency for decline in fat content continues with each day until the 17th day of feeding when the lowest point is reached. For Group II the lowest point is reached on the 19th day of cod liver oil feeding.

From figure 1, it will also be seen that the recovery to normal fat percentage is slow after removal of the cod liver oil from the ration. It will

be noticed that there is a fairly constant increase in fat percentage up to the 16th day after removal of the cod liver oil.

From the data there is no evidence that cod liver oil influenced the amount of milk. The fluctuations in daily milk production appear about equal in cod liver oil periods and basal ration periods.

Summary and Conclusions—The effect of feeding cod liver oil to milking cows is reported.

In every case when cod liver oil to the extent of five ounces daily was added to the ration, there was a marked decline in the fat percentage of the milk with no apparent effect upon the amount of milk.

The depressing effect of cod liver oil seems to be cumulative for a time, at least.

REFERENCES

(1) Brown, J. B., and T. S. Sutton. Journal of Dairy Science **14**: 125–135.
(2) Bünger, H. Tierernähr. **1**: 408–420. 1930.
(3) Channon, H. J., J. C. Drummond, and J. Golding. Analyst **49**: 311–327. 1924.
(4) Drummond, J. C., H. J. Channon, K. H. Coward, J. Golding, J. Mackintosh, and S. S. Zilva. Jour. Agri. Science **14**: 531–547.
(5) Golding, J., and S. S. Zilva. Biochem. J. **22**: 173–182. 1928.
(6) Harvey, Douglas. Biochem. J. **21**: 1268–76. 1927.
(7) Mattick, E. C. V. Biochem. J. **22**: 144–149. 1928.
(8) Petersen, W. E. Journal of Dairy Science **10**: 70–82. 1927.

THE USE OF SKIMMILK POWDER IN GRAIN RATIONS FOR DAIRY CALVES*

M. H. BERRY

Maryland Agricultural Experiment Station, University of Maryland, College Park, Maryland

INTRODUCTION

Experimental results have shown that powdered skimmilk fed dry to calves in their grain ration is the cheapest and most satisfactory method of feeding it if milk feeding is to be continued for a period of more than two months. (1), (2), (3), (4), (5).

Recent investigational work in calf feeding is on the preparation of home-mixed calf rations to be used dry as grain rations or as calf meal gruels as substitutes for milk. Most of these mixtures contain skimmilk powder, varying in amount from 10 to 40% or more. (6), (7), (8), (9), (10).

To secure some information regarding the value of adding skimmilk powder to such mixtures and the amount advisable to add, this work was undertaken.

EXPERIMENTAL

Thirty purebred calves from the Experiment Station herd were used as experimental animals in this study. These calves were not all started on the experiment at the same time, but were started as they were dropped. They were a fairly uniform group and a good representation of normal calves. From birth to eight weeks of age they were allowed to nurse a cow, enough calves nursing one cow so that each calf did not receive more than six to eight pounds of milk daily. At eight weeks of age the calves were weaned to dry grain and hay and divided into three groups of ten calves each. Each group contained seven females and three males.

Group I, which served as a check group, received a grain ration composed of 100 lbs. wheat bran, 100 lbs. corn meal, 100 lbs. ground oats, and 50 lbs. linseed oil meal.

Group II received the same grain ration as Group I except that 100 lbs. or 22+% of skimmilk powder was added to the ration after the calves were weaned at eight weeks of age.

Group III received the same grain ration as Group I except that 200 lbs. or 36+% of skimmilk powder was added to the ration after the calves were weaned at eight weeks of age.

Received for publication November 13, 1931.

* Published with the approval of Director H. J. Patterson as a contribution from the Maryland Agricultural Experiment Station, November 10, 1931.

Individual grain feeding was practiced throughout the trial. In order to have results uniform the following grain feeding schedule was rigidly adhered to in the feeding of all three groups.

Birth to 7th week	Nursed cow twice daily Free access to regular grain mixture
7th week to 8th week	Nursed cow once daily Fed 1 lb. grain mixture daily
8th week to 10th week	Fed 2 lbs. grain mixture daily
10th week to 13th week	Fed 3 lbs. grain mixture daily
13th week to 21st week	Fed 4 lbs. grain mixture daily

The grain mixture was supplemented with clover hay (U. S. No. 1 grade), fed *ad libitum*. Fresh water was kept before the calves at all times. They were turned out daily for exercise, when the weather was satisfactory. Salt was made available in boxes in the exercise lots. Daily observations were made of their general condition. Weights were obtained weekly. Photographs were taken of each individual calf at the end of the experimental feeding period for the comparison of growth and development. The results of the feeding trial are based on data collected on each calf from weaning, at eight weeks of age, to twenty one weeks of age, or a period of 91 days.

DISCUSSION

The results obtained in this trial are reported in tables 1 to 4. Table 4 gives a summary of the results obtained. These results give an estimation of the value of adding skimmilk powder to grain rations for dairy calves. An examination of the growth and cost data in this table shows that the calves in Groups I, II, and III made average daily gains of 1.30, 1.38, and 1.49 pounds, respectively. The calves in Group II made an average of 0.08 of a pound and those in Group III 0.19 of a pound more daily gain per calf than was secured per calf in Group I. This increased gain was produced at a cost of $.47 per pound on the calves in Group II and at $.32 per pound on the calves in Group III. The average cost per pound of gain, not including the cost of the roughage fed, for Groups I, II, and III was $.033, $.058 and $.069, respectively.

Throughout the entire experimental period the calves in the three groups continued to appear normal in all outward respects. Several experienced judges were unable to distinguish between the calves of the different groups.

RESULTS

Growth Data For Calves

TABLE 1

Growth data for each calf in Group I—grain ration without skimmilk powder

WEEKS	NUMBER OF CALF									
	347	370	371	427	430	431	436	444	447	452
Weight at birth (lbs.)	80	85	70	70	75	70	80	*	*	90
Weight at 8 wks. (lbs.)	120	155	130	135	130	125	120	170	140	145
9	125	175	135	155	140	140	130	180	145	160
10	130	180	145	160	155	145	140	185	160	165
11	135	200	155	175	165	155	150	195	165	175
12	145	205	165	185	170	165	165	205	175	185
13	140	210	170	190	180	170	165	205	180	185
14	140	225	170	195	185	175	170	220	200	195
15	155	230	180	200	190	180	185	230	205	210
16	165	240	190	205	200	185	195	245	215	220
17	175	245	205	215	200	195	205	250	230	225
18	185	265	210	215	210	210	220	260	235	230
19	195	280	225	215	230	220	225	270	250	250
20	205	290	230	225	240	235	225	280	260	250
21	215	300	240	240	250	245	240	290	270	265
Gain in weight (lbs.)**	95	145	110	105	120	120	120	120	130	120
Av. weekly gain (lbs.)**	7.31	11.15	8.46	8.08	9.23	9.23	9.23	9.23	10.00	9.23
Av. daily gain (lbs.)**	1.04	1.59	1.21	1.15	1.32	1.32	1.32	1.32	1.43	1.32

* Birth weight not obtained.

**For experimental grain feeding period—91 days.

Breed and sex of calves in Group I:

347—Guernsey male
370—Ayrshire "
371—Jersey "
427—Ayrshire female
430— " "
431—Guernsey female
436—Ayrshire "
444—Holstein "
447— " "
452—Ayrshire "

TABLE 2

Growth data for each calf in Group II—22+% of grain ration skimmilk powder

WEEKS	NUMBER OF CALF									
	348	372	376	425	426	428	437	438	445	449
Weight at birth (lbs.)	55	75	80	80	70	70	95	60	*	*
Weight at 8 wks. (lbs.)	90	160	135	145	145	120	140	140	155	155
9	95	165	145	155	155	135	155	145	165	165
10	100	175	160	160	170	145	160	155	175	175
11	105	185	165	160	180	150	175	160	180	190
12	105	195	170	175	190	155	185	170	190	195
13	110	210	175	185	200	165	195	180	200	205
14	115	220	175	190	210	170	205	185	210	215
15	125	230	185	190	220	180	210	195	220	225
16	135	240	200	205	240	195	220	205	235	235
17	150	260	210	220	245	205	235	210	250	250
18	155	275	220	220	250	205	240	210	255	275
19	165	280	230	225	265	215	255	235	260	280
20	175	305	230	230	275	230	265	245	280	290
21	185	310	245	235	285	250	275	250	300	305
Gain in weight (lbs.)**	95	150	110	90	140	130	135	110	145	150
Av. weekly gain (lbs.)**	7.31	11.53	8.46	6.92	10.77	10.00	10.38	8.46	11.15	11.53
Av. daily gain (lbs.)**	1.04	1.65	1.21	.99	1.54	1.43	1.48	1.21	1.59	1.65

* Birth weight not obtained.

**For experimental grain feeding period—91 days.

Breed and sex of calves in Group II:

348—Jersey male
372—Ayrshire male
376—Guernsey "
425—Guernsey female
426—Ayrshire "
428—Ayrshire female
437— " "
438—Jersey "
445—Holstein "
449— " "

TABLE 3

Growth data for each calf in Group III—36 + % of grain ration skimmilk powder

WEEKS	NUMBER OF CALF									
	346	379	383	429	435	446	448	450	454	457
Weight at birth (lbs.)	70	60	100	65	90	*	*	70	70	95
Weight at 8 wks. (lbs.)	120	135	140	120	140	165	150	125	120	145
9	135	145	160	135	150	175	160	130	125	155
10	145	160	165	145	160	190	170	140	130	160
11	155	170	175	155	170	200	180	150	140	160
12	160	180	185	165	180	205	190	160	140	175
13	165	195	195	170	190	225	195	160	155	185
14	180	205	210	185	200	235	205	175	165	195
15	185	215	220	200	215	245	215	190	180	200
16	200	220	225	210	220	255	230	195	190	210
17	210	225	235	230	230	265	245	205	200	220
18	215	235	245	230	235	280	260	215	205	235
19	230	240	255	245	245	290	270	225	220	250
20	240	250	275	255	250	295	290	230	230	255
21	255	270	285	270	260	310	300	245	250	270
Gain in weight (lbs.)**	135	135	145	150	120	145	150	120	130	125
Av. weekly gain (lbs.)**	10.38	10.38	11.15	11.53	9.23	11.15	11.53	9.23	10.00	9.62
Av. daily gain (lbs.)**	1.48	1.48	1.59	1.65	1.32	1.59	1.65	1.32	1.43	1.37

* Birth weight not obtained.

**For experimental grain feeding period—91 days.

Breed and sex of calves in Group III:

346—Guernsey male
379—Jersey male
383—Ayrshire male
429—Ayrshire female
435— " "
446—Holstein female
448— " "
450—Guernsey "
454—Jersey "
457—Ayrshire "

TABLE 4

Growth, feed, and cost data for the average calf by groups for the experimental feeding period

GROUP	GAIN IN WEIGHT (LBS.)			LBS. SKIMMILK POWDER FED PER CALF	LBS. GRAIN FED PER CALF	TOTAL LBS. GRAIN AND SKIMMILK POWDER FED PER CALF	COST OF GRAIN AND SKIMMILK POWDER FED PER CALF	COST PER POUND GAIN*
	Total	Weekly	Daily					
I	118.5	9.11	1.30	None	315	315	$3.94	$ .033
II	125.5	9.65	1.38	70.0	245	315	$7.26	$ .058
III	135.5	10.42	1.49	114.5	200.5	315	$9.38	$ .069

* Cost figures do not include roughage fed.
Grain was charged at $25.00 per ton and skimmilk powder at $6.00 per hundred.

CONCLUSION

So far as could be measured by growth-weights and general observations, it was concluded that the increased weight or growth obtained by the addition of a large percentage of dried skimmilk powder to the grain rations of dairy calves, after they had had a good start on milk, incurred more expense than the results would justify.

REFERENCES

(1) KRAUSS, W. E., and CRAWFORD, C. H. Powdered Skimmilk as a Feed for Dairy Calves. Ohio Sta. Bimo. Bul. 14, No. 2, 49–56. 1929.
(2) RUPEL, I. W., and BOBSTEDT, G. Calves Grow Well on Dried Smimmilk. Wis. Sta. Bul. 410, 81–82. 1930.
(3) BECHDEL, S. I. Experiments with Skimmilk Powder in the Rations of Dairy Calves. Pa. Sta. Bul. 213, 19–20. 1927.
(4) CRAWFORD, C. H., and KRAUSS, W. E. Calf Feeding. Ohio Sta. Bul. 431, 144. 1929.
(5) ELLINGTON, E. V., and KNOTT, J. C. The Use of Dry Skimmilk in Feeding Dairy Calves. Wash. Col. Bul. 245, 28–29. 1930.
(6) JONES, I. R., BRANDT, P. M., and WILSON, F. D. Raising Calves on Dry Calf Meals. Ore. Sta. Bul. 290, 1–30. 1931.
(7) CAINE, GEORGE B. Raising Dairy Calves. Utah Sta. Cir. 87: 12. 1930.
(8) CRAWFORD, C. H. Progress Report of Calf Feeding Trials at Cornell University and correspondence (Oct., 1931) between Mr. C. H. Crawford and author.
(9) KNOTT, J. C. Feeding Dry Skimmilk to Calves. Hoards Dairyman, 76: No. 18, 634–653. Sept. 25, 1931.
(10) BORLAND, A. A., and BECHDEL, S. I. New Calf Feeding Facts. The Dairy Farmer, 26: No. 8, 10, 50, 51. Sept., 1928.

A FORMULA FOR EVALUATING FEEDS ON THE BASIS OF DIGESTIBLE NUTRIENTS[1]

WM. E. PETERSEN

Division of Dairy Husbandry, University of Minnesota

The nutritive value is an important consideration in the selection of a feed, although not the only consideration. The modern feeding standards prescribe the requirements of the cow in terms of digestible crude protein and total digestible nutrients and intelligent feeders appreciate the necessity of supplying the minimum amounts of the two groups of nutrients for good results.

It is common knowledge that feeds vary greatly in composition and in price. It is also factual that high protein feeds as a rule are higher priced than lower protein feeds and that the difference varies from year to year. In the purchase of a feed, therefore, two questions must be answered: First, does it supply the required nutrients, and second, is it a reasonably cheap source of these nutrients?

The problem of economical source of nutrients has long been recognized and attempts have been made to indicate relative cheapness of nutrients in different feeds. One of the most familiar is to charge the entire cost of the feed to either the protein or the total digestible nutrients and express the results in cost per pound. The fallacy of this method is apparent as high protein feeds contain nonprotein nutrients for which it should have credit even though purchased chiefly for its protein content. Likewise feeds purchased chiefly for total digestible nutrients have protein for which they should be credited. The chief objection to this method, however, comes in evaluating medium protein foods where both protein and total digestible nutrient costs become relatively high.

Hayden of Ohio proposed a more accurate, though cumbersome, method for evaluating feeds. It consisted of establishing a value per pound of nutrients in corn by dividing the cost by the total nutrients. Then the value of protein was calculated by:

1. Determining the "excess protein" in linseed oilmeal by calculating all nonprotein nutrients plus sufficient protein to give the same composition as corn. The remaining protein was designated as "excess protein."

2. Crediting linseed oilmeal with its corn equivalent by multiplying the number of pounds by the price established per pound of nutrients in corn.

Received for publication November 13, 1931.

[1] Published with the approval of the Director as Paper No. 1050, Journal Series, Minnesota Experiment Station.

3. Subtracting computations of 2 from price of linseed oilmeal.
4. Dividing results of (3) by number of pounds of excess protein.

Hayden designates this as the cost per pound of "excess protein."

It is believed that Hayden's method gives accurate results but is rather too cumbersome for extensive use. The formula hereafter presented has been used by students in feeding at the University of Minnesota and has been found usable and practical. The evaluation is arrived at by using cottonseed meal and corn as the two base feeds, respectively the cheapest source of protein and total digestible nutrients.

One hundred pounds of 43 per cent protein cottonseed meal contains 37.6 pounds digestible protein and 42.6 pounds of nonprotein digestible nutrients. Fifty-seven and twenty-four hundredth pounds No. 2 corn contains 42.6 pounds nonprotein total digestible nutrients and 4.1 pounds digestible protein. Therefore, 57.24 pounds corn can be subtracted from 100 pounds cottonseed meal leaving 33.5 pounds digestible protein. It is reasonable to ascribe any difference in cost between 100 pounds cottonseed meal and 57.24 pounds corn to the 33.5 pounds digestible protein and by simple division arrive at the value of 1 pound of digestible protein. To find the value of the nonprotein total digestible nutrients, credit either feed with its protein value and the difference from the cost of the feed is charged to the nonprotein digestible nutrients.

The formula for determining the cost for a pound of protein is:

$$\frac{\text{Cost of 100 pounds cottonseed meal} - .5724\ (\text{cost of 100 pounds corn})}{33.5}$$

Example: Substituting with cottonseed meal at \$50.00 per ton and corn at \$25.00 per ton

$$\frac{\$2.50 - (.5724 \times \$1.25)}{33.5} = 5.328 \text{ cents}$$

The value of a pound of nonprotein digestible nutrients may be arrived at by the following formula

$$\frac{\text{Cost of 57.24 pounds corn} - (\text{value of protein} \times 4.1)}{42.6}$$

Again substituting with corn at \$1.25 per hundredweight and protein at 4.328 cents per pound

$$\frac{1.25 \times 57.24 - (4.1 \times 5.328)}{42.6}$$

or 1.167 cents per pound.

Should some other feeds be a cheaper source of either protein or nonprotein nutrient such feeds may be used to establish the value of either protein or nonprotein nutrients. This however is seldom necessary as by using corn and cottonseed meal as base feeds other cheaper feeds would be

indicated, as selling for less than their value on the basis of corn and cottonseed meal.

By applying these values to the digestible protein and nonprotein digestible nutrients of other feeds their values are arrived at. It is apparent that for a given feed both cottonseed meal and corn exert a definite influence on its value and therefore constants can be determined for each

TABLE 1

Giving constants by which corn and cottonseed meal prices must be multiplied to give values of more common feeds

	CONSTANT		VALUE WHEN	
	For cottonseed meal	For corn	Corn is $20.00 and cottonseed meal $40.00	Corn is $20.00 and cottonseed meal $30.00
Oats	.116	.749	$19.62	$18.46
Wheat	.062	.909	20.68	20.04
Barley	.067	.907	20.82	20.15
Rye	.064	.940	21.38	20.72
Soybeans	.709	.342	35.23	28.11
Flaxseed	.380	.885	32.90	29.10
Corn and cottonseed meal	.024	.980	18.64	18.88
Bran	.222	.512	19.18	16.90
Middlings	.240	.613	21.86	19.46
Linseed oilmeal	.765	.207	34.74	27.09
Gluten meal	1.043	−.040	40.92	30.49
Gluten feed	.466	.532	29.27	24.62
Soybean meal	1.054	.010	42.21	31.62
Beet pulp	− .054	.930	16.44	16.98
Molasses	− .137	.863	11.78	13.15
Mangels	.014	.065	1.86	1.72
Potatoes	− .013	.225	3.98	4.11
Alfalfa	.201	.427	16.58	14.57
Red clover	.100	.509	14.18	13.18
Sweet clover	.212	.413	16.77	14.62
Mixed hay	.026	.578	12.60	12.34
Timothy	− .049	.647	10.98	11.47
Prairie	− .040	.630	11.00	11.40
Corn fodder	− .016	.603	11.42	11.58
Corn stover	− .039	.484	8.12	8.51
Corn silage	− .008	.214	3.96	4.04
Oat straw	− .098	.655	9.20	10.18

How to use the table:

Look for constants under head "For cottonseed meal" following the feed, the value of which is desired. Multiply the price of cottonseed meal per ton by this factor, then multiply the price of corn per ton by factor found under head, "For corn." Add the two products which is the value per ton of the feed under consideration.

Note—If the constant is preceded by a − (minus) sign, subtract in place of adding.

feed which when applied to the prices of cottonseed meal and corn should give the correct value of the feed.

By calculating the values of a feed with corn constant and cottonseed meal at two different values a constant can be determined by which cottonseed meal may be multiplied to indicate the influence upon the price of the feed. Likewise constants may be determined for corn.

Example: Using previous formulae oats have a value of $19.61 per ton when cottonseed meal is $40.00 and corn $20.00 per ton, and $18.45 per ton when corn is $20.00 and cottonseed meal $30.00 per ton. Therefore a $10.00 increase in cottonseed meal increases the value of oats $1.16.

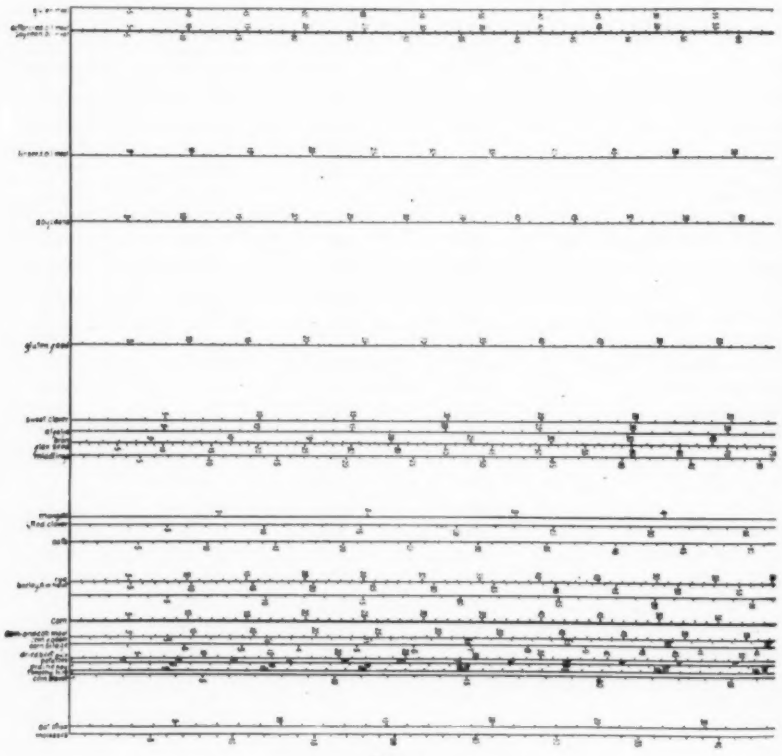


FIG. 1

Chart for evaluation of feeds upon basis of value of corn and cottonseed meal. To determine the value per ton of any feed on the chart place straight edge on value of corn, the heavy line toward the right, and on cottonseed meal, the heavy line toward the left. The point of intersection on the scale for any feed gives its value in dollars per ton.

Keeping the price of cottonseed meal constant and increasing the price of corn we find that a $10.00 increase in price of corn increases the value of oats $7.49. For any price therefore the value of oats = .116 × price of cottonseed meal + .749 × price of corn.

The following table gives the constants by which cottonseed meal prices and corn prices must be multiplied to give the values of the more common feeds. Values with corn at $20.00 and cottonseed meal at $30.00, and corn at $20.00 and cottonseed meal at $40.00 are given.

A GRAPH FOR DETERMINING VALUE OF COMMON FEEDS

It also becomes apparent a graph can be constructed by which the value of any feed can be determined on the basis of values of corn and cottonseed meal. This is done in figure 1. This graph is constructed by placing the proper divided scale for any feed in the proper place between corn and cottonseed meal. The scale is ascertained by determining the value of that feed when corn and cottonseed meal are $60.00 per ton each, and dividing into the proper sectors. The location of the scale is determined by the relative influence of corn and cottonseed meal upon the value of the feed such scale represents.

THE RELATION OF THE SOLUBLE PORTION OF ALFALFA TO THE RAPID ABSORPTION OF FEED FLAVOR IN MILK

C. L. ROADHOUSE AND J. L. HENDERSON
Dairy Industry Division, University of California, Davis

Feed as a source of flavor in milk has been known for more than a century (1) and the absorption of feed flavors in milk soon after the feed has been consumed has been reported by investigators in recent times (2) to (6). Although it has been generally accepted that feed is an important source of flavor in milk when given to cows previous to milking, it has not been previously described how the feed flavor could appear in the milk 20–30 minutes after the ingestion of the feed, since the feed ordinarily remains in the rumen several hours before it passes on to the abomasum or fourth stomach and the intestinal tract where absorption takes place. Schalk and Amadon (7) in their study of the physiology of rumination pointed out that as soon as roughage was swallowed by the animal and passed into the rumen it was flooded with waves of liquid forced into the rumen from the second stomach. This action takes place with each peristaltic contraction of the rumen. This offered to the writers a possible explanation for the presence of the feed flavor in milk soon after flavor-producing feeds were consumed by the animal. The present experiment was undertaken to study the rate at which the juice of the alfalfa plant made its appearance as a feed flavor in the milk.

EXPERIMENTAL

Green alfalfa, cut just before the bloom stage, was immediately placed in the cold storage room at 15° F. and thoroughly frozen. The purpose of the freezing was to rupture the plant cell walls, thus aiding in the extraction of juice from the plant tissues (8). After thawing the alfalfa at room temperature, it was cut into fine pieces by the use of a food grinder and the liquid pressed out of the pulp and filtered to remove all solid particles. This juice was then administered to the cows as a drench. The liquid from 25 pounds of alfalfa amounted to between 5 and 6 quarts and this quantity was used in each case as the standard drench. It required 3½ to 5 minutes for 2 men to administer the juice. Cows producing milk with good flavor were selected from the University Farm Herd, and all feed was withheld from the cows for five hours previous to milking in order to eliminate extraneous sources of feed flavor.

Received for publication November 20, 1931.
Acknowledgment is made to the Animal Husbandry Division for the use of animals and facilities for the conduct of this experiment.

The cows were partially milked before drenching in order to secure a sample with normal flavor. Other portions of the milk in the udder were drawn every five minutes after drenching for 30 minutes. In some instances, however, samples were drawn at the end of 45 minutes, one hour, and two hours following drenching. The milk samples collected were scored for flavor within two hours after the last sample had been drawn. The samples were numbered in such a way that their identity was unknown to the judges.

TABLE 1

Flavor Comments on Milk of Cow Number 153 Before and After Administration of Alfalfa Juice

INTERVAL AFTER DRENCHING BEFORE MILK SAMPLES WERE DRAWN (IN MINUTES)	SCORE	COMMENTS
Control-sample taken before drenching*	13.5	No feed flavor
5	13.5	No feed flavor
10	13.4	No feed flavor—slightly astringent
15	13.4	No feed flavor—slightly astringent
20	13.3	Slight feed flavor
25	13.2	Feed flavor and odor
30	13.2	Feed flavor and odor
Control-sample taken before drenching**		No feed flavor
5		No feed flavor
10		No feed flavor
15		Slight odor. No feed flavor
20		Very slight feed flavor
25		Slight feed flavor and odor
30		Slight feed flavor and odor
60		Distinct feed flavor and odor

* TRIAL I—Cow No. 153—5 quarts of liquid from 25 pounds of alfalfa used as a drench. Time required to drench 5 minutes. Cow was maintained on oat hay and concentrate rations. No feed given 5 hours before drenching.

** TRIAL II—Cow No. 153—6 quarts of liquid from 25 pounds of alfalfa used as a drench. Time required to administer drench 5 minutes. Cow maintained on alfalfa and concentrate rations. No feed given 5 hours before drenching.

DISCUSSION OF RESULTS

The data show that twenty minutes after drenching the cows with juice expressed from the green alfalfa plant, feed flavor was present in the milk. It had been observed that feed flavor appears in the milk 20 to 30 minutes after a cow has eaten 15 to 20 pounds of green alfalfa (6). This experiment indicates that the flavor-producing materials are present in the liquid that is expressed from the feed during partial mastication in the mouth and released during the maceration process in the rumen. In the case of

TABLE 2

Flavor Comments on Milk of Cows Numbers 441 and 428 Before and After Administration of Alfalfa Juice

INTERVAL AFTER DRENCHING BEFORE MILK SAMPLES WERE DRAWN (IN MINUTES)	SCORE	COMMENTS
Control-sample taken before drenching*		No feed flavor
5		No feed flavor
10		No feed flavor
15		Very slight feed flavor
20		Slight feed flavor and odor
25		Definite feed flavor and odor
30		Slight feed flavor and odor
60		Strong feed flavor and odor
120		Distinct feed flavor and odor
Control-sample taken before drenching**	13.5	No feed flavor
5	13.5	No feed flavor
10	13.5	No feed flavor
15	13.5	No feed flavor
20	13.2	Slight feed flavor and odor
30	13.1	Feed flavor and odor
45	13.0	Definite feed flavor and odor
60	13.2	Definite feed flavor and odor
120	13.4	Very slight feed flavor and odor

* Cow No. 441—5 quarts of liquid expressed from 25 pounds of alfalfa used as a drench. Time required to drench 5 minutes. No feed given 5 hours before drenching. Cow maintained on oat hay and concentrate rations. The one-hour sample had a more prominent feed flavor than the two-hour samples.

** Cow No. 428—5 quarts of liquid expressed from 25 pounds of alfalfa was used as a drench. Cow was maintained on alfalfa and concentrate rations. No feed received 5 hours before drenching.

dry feed, such as alfalfa or clover hay, in which there is considerable flavor producing material, the waves of liquid passing over the feed in the rumen after it is swallowed apparently extract a portion of the flavor producing materials from the feed and carry them on through the digestive tract where they are rapidly absorbed. Normally the feed eaten by ruminants remains in the rumen for a considerable time before it is returned to the mouth for final mastication and passage on through the alimentary tract for absorption. Most of the liquid passes on immediately.

The rapid absorption of the juices rather than the solid portions of the feed, would seem to be concerned with the early absorption of feed flavor in milk. It was found with alfalfa juice that the most prominent feed flavor was present in samples drawn 45 to 60 minutes after drenching.

In previous experiments where green or dry alfalfa was given to cows the most prominent feed flavor was observed in the milk two hours after the feed was placed before the cows. It is apparent that the juice of the alfalfa plant carries a considerable portion of the flavor-producing materials and that the administration of this juice as a drench leads to more rapid absorption by the animal.

CONCLUSIONS

(1) Feed flavor appears in the milk twenty minutes after the ingestion of flavor-producing materials in liquid form.

(2) The most pronounced feed flavor was present in the milk drawn 45 to 60 minutes after drenching.

REFERENCES

(1) HARLEY, WILLIAM. The Harleian Dairy System (1829). James Eidgway, Piccadilly, London.

(2) GAMBLE, J. A., and KELLY, ERNEST. The Effect of Silage on the Flavor and Odor of Milk. U. S. D. A. Bulletin No. 1097. 1922.

(3) BABCOCK, C. J. Effect of Feeding Green Alfalfa and Green Corn on Flavor and Odor of Milk. U. S. D. A. Bulletin No. 1190. 1923.

(4) ————————. Effect of Feeding Cabbage and Potatoes on Flavor and Odor of Milk. U. S. D. A. Bulletin No. 1297. 1924.

(5) ————————. Effect of Garlic on Flavor and Odor of Milk. U. S. D. A. Bulletin No. 1326. 1925.

(6) Report of Agricultural Experiment Station of the University of California, page 62. 1926.

(7) SCHALK, A. F., and AMADON, R. S. Physiology of the Ruminant Stomach (Bovine). Bulletin No. 216 Agricultural Experiment Station, North Dakota Agricultural College.

(8) OSBORN, T. B., WAKEMAN, A. J., and LEAVENWORTH, C. S. The Proteins of the Alfalfa Plant. Journal Biological Chemistry **49**: 63–91. 1921.

A STUDY OF METHODS USED IN CONDUCTING A SILAGE FEEDING EXPERIMENT

AVERY D. PRATT*

Department of Dairy Husbandry, Storrs Agricultural Experiment Station, Storrs, Conn.

This paper deals with the methods employed in the conduct and analysis of the data of the silage feeding experiment reported in Bulletin 169 of the Storrs Station. (1)

Data are presented which justify the use of long experimental periods, a practice that is becoming well established in later years.

An analysis is presented of a method of weighing which gives great accuracy and eliminates forty per cent of the labor of weighing. Data are also presented which indicate equal accuracy in morning and afternoon weighing.

A method is presented of measuring the efficiency of milk production of experimental animals.

LENGTH OF PERIODS

In the silage experimental work of this station it has been the practice to provide a 20 day preliminary period to precede the 100 day experimental period. The experimental period was intended to be 100 days in length in each trial of this experiment but the second trial was discontinued at 70 days because of the advanced stage of lactation of most of the cows. A study of average group production for the individual or combined trials does not show any consistent change in efficiency (the method of determining efficiency is shown on page 308) which would have affected the results had the preliminary period been but 10 days. The efficiency of both groups would have been higher had the experimental period been 30 instead of 100 days but it would not have affected the comparison of the two groups, the light silage group would still have produced more efficiently. A study of the data for individuals, however, shows that some animals do not adjust themselves to a change quickly enough that a preliminary period of less than 20 days is justified. This is especially true if the ration is not properly adjusted at the start to the capacity of the cow. An example of this is seen in the daily feed record of Korndyke for the first 30 days of the first trial which is recorded in table 1.

For the first two days Korndyke ate nearly 10 pounds of hay at each feeding but refused on the fifth feeding and had her hay reduced to 9

Received for publication December 4, 1931.

* Now a member of the Department of Dairy Husbandry, Virginia Polytechnic Institute, Blacksburg, Va.

TABLE 1

Daily food consumption of Korndyke

DAY OF EXPERIMENT	GRAIN	SILAGE	HAY	
			Fed	Refused
	pounds	*pounds*	*pounds*	*pounds*
1	10	18	20.0	0.7
2	10	18	20.0	0.3
3	10	18	19.0	3.8
4	10	18	18.0	0.4
5	10	18	18.0	0.0
6	10	18	18.0	0.0
7	10	18	18.0	0.4
8	10	18	18.0	0.3
9	10	18	18.0	0.3
10	10	18	18.0	0.1
11	9.9	18	18.0	0.3
12	9.8	18	18.0	0.7
13	9.6	18	18.0	0.1
14	9.4	18	18.0	0.2
15	9.2	18	18.0	0.1
16	9.0	18	18.0	0.6
17	8.8	18	18.0	2.0
18	8.6	18	15.0	4.4
19	8.4	18	12.0	0.0
20	8.2	18	12.0	0.0
21	8.0	18	12.0	0.0
22	8.0	18	12.5	0.0
23	8.0	18	13.0	0.0
24	8.0	18	13.5	0.0
25	8.0	18	14.0	0.1
26	8.0	18	14.0	0.1
27	8.0	18	14.1	0.0
28	8.0	18	14.2	0.0
29	8.0	18	14.2	0.0
30	8.0	18	14.2	0.0

pounds which she consumed for 14 days refusing on an average 0.2 pounds until on the 18th day she refused 4.4 pounds of hay. The hay was then reduced to 6 pounds per feeding for three days, after which it was increased to 6.5 pounds for two days and then finally to 7 pounds at each feeding (14 pounds daily) which she continued to consume for the remainder of the experiment. Had she received 8 pounds or 8.5 pounds at first she might have continued to consume that for 30 days or more without refusing whereas her actual capacity was approximately 7 pounds of hay with the silage and grain which she received. It is of interest that her weight fell off shorply for twelve days in spite of the fact that she was being overfed and then fluctuated to the end of the 20 day preliminary period

when it became comparatively stable. It will be noted that the second reduction in hay consumption occurred despite a parallel reduction in grain. There would have been a marked effect upon the feed consumption if these data had been for the second or reversed period of an experiment of the reversal type with the first seven days acting as a 7 day interval.

WEIGHING

In the previous experiments of this station it has been the practice to weigh all animals daily to the nearest pound. In these experiments the main purpose of the weights has been to guide the feeding practice.

Three successive days weights were averaged (the fourth and fifth omitted) for each five day period of a previous experiment and the resulting averages plotted against the average of five daily weights. Changes in the feeding program of the experiment utilized for this comparison had been dependent upon averages of daily weights for the previous 10 days. It was thought the method would be open to criticism if not based upon weights of animals whose changes in feeding program had been dependent upon an average of three successive days weights for each five day period. Lush (2) has averaged three successive days weights in analyzing growth experiments. If comparative gains in the weights of two groups are being studied there is much greater need of accuracy than in this experiment where weight change was but one of the criteria which determined changes in the ration.

In the first feeding trial of this experiment the cattle were weighed daily at 8 A. M. to the nearest pound. An analysis of the weights obtained is shown in table 2.

TABLE 2

A comparison of daily weighing with weighing three successive days of each five day period

	DAILY WEIGHING	WEIGHING THREE SUCCESSIVE DAYS OF EACH FIVE-DAY PERIOD
Mean weight (lbs.)	1113.	1113.
Standard deviation (lbs.)	11.8	11.7
Probable error (lbs.)	± 7.96	± 7.89
Percentage coefficient of variability	1.06	1.05

The weights of the entire group of cows, eight in number, were analyzed for the experimental period of 100 days, or a total of 800 weighings. It will be noted that the mean weight was the same by both methods and that the probable errors and percentages coefficients of variability differed but slightly. This indicates a greater degree of accuracy than that obtained by Lush and Black (3) who state that "The error of estimate from a 3 days

weight was 58% as large as from a 1 day weight. Ten weighings would be required to reduce the error to one third what it was from a single weight." Accordingly, the animals were weighed but three days of each five day period of the second and third trials.

In the third trial afternoon weighing was more convenient. The group of ten animals were weighed both at 8 A. M. and at 1 P. M. three successive days in each 5 day period for thirty days. A comparison of morning and afternoon weighing is presented in table 3. The data are based upon eight-

TABLE 3

A comparison of morning and afternoon weighing

	8 A. M.			1 P. M.		
	Mean weight	Probable error	Percentage coefficient of variability	Mean weight	Probable error	Percentage coefficient of variability
Heavy silage group	*pounds*	*pounds*		*pounds*	*pounds*	
Queen	1371	± 7.2	.92	1346	± 6.1	.68
Secret	970	± 4.1	.63	955	± 4.0	.62
Laureate	1123	± 6.2	.82	1101	± 8.0	1.08
Jasmine	826	± 4.9	.87	810	± 3.8	.70
Favorite	774	± 6.0	1.15	768	± 6.1	1.18
Group average	1013	± 3.4	.49	996	± 3.4	.50
Light silage group						
Korndyke	1187	± 6.3	.78	1160	± 7.9	1.00
Graceful	1008	± 4.5	.66	989	± 4.7	.70
Amiable	1090	± 4.7	.64	1083	± 5.3	.73
Tontine	874	± 4.1	.70	862	± 3.4	.58
Brilliant	747	± 3.7	.74	734	± 4.7	.94
Group average	981	± 3.3	.40	966	± 3.2	.49
Average of both groups	997	± 2.7	.41	981	± 2.7	.41

een weighings for each animal, or a total of 180 weights for both morning and afternoon. No consistent differences can be observed in the probable error or percentage coefficients of variability for individual animals between morning and afternoon weighings. When the Heavy Silage and Light Silage Groups are considered as entities the magnitude of the probable errors and percentage coefficients of variability is much smaller than for individuals due to the greater number of weighings considered. When both groups are considered collectively the probable error is reduced to ± 2.7 pounds and the percentage coefficient of variability to 0.41 for both morning and afternoon weighing. By comparing the probable errors and percentage coefficients of variability for individual animals with those of the two groups and for the average of both groups it will be seen that

the deviations from the mean are compensating rather than cumulative. This indicates careful control of experimental conditions.

The absence of any considerable differences between the Heavy Silage and Light Silage Groups in these respects indicates that the type of ration did not alter the accuracy as between morning and afternoon weighing.

Afternoon weighing is therefore as accurate as morning weighing but the mean morning weight was 16 pounds greater than the afternoon weight. This difference in weight is significant since it is six times as great as the probable error. This difference in weight can be accounted for when it is considered that the cows were fed silage and grain at 6 A. M. followed by hay feeding. Water was before them in a water cup and they drank following hay feeding prior to the 8 A. M. weighing. From 8 A. M. to 1 P. M. they drank proportionately less and lost weight by excretion and respiration. The difference in the mean morning and afternoon weights emphasizes the necessity of weighing at the same hour each day.

EFFICIENCY OF PRODUCTION

For a comparative experiment an equable basis of comparison is imperative. In this experiment it is desirable to relate milk production to dry matter consumption for each group. Solids not fat, butterfat, or even

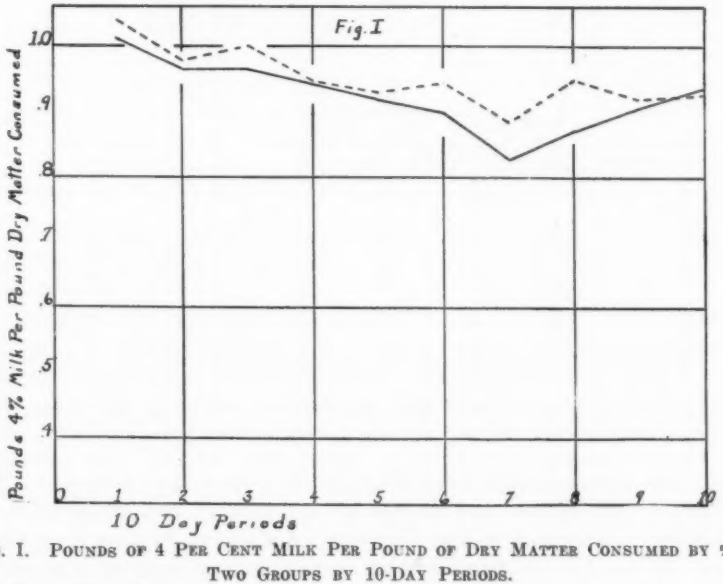


FIG. I. POUNDS OF 4 PER CENT MILK PER POUND OF DRY MATTER CONSUMED BY THE TWO GROUPS BY 10-DAY PERIODS.

Heavy Silage Group ————.
Light Silage Group - - - - - - - -.

total solids is not satisfactory as a basis of comparison since the total energy content is not considered. Gaines and Davidson (4) have derived a formula by which actual production can be converted on an energy basis to an equivalent amount of 4 per cent milk. This formula ($.4 \times$ milk $+ 15 \times$ fat = equivalent 4 per cent milk) has been used to convert the production to 4 per cent milk, which is a satisfactory basis of comparison for this purpose. The amounts of 4 per cent milk produced and of dry matter consumed have been calculated for 10 day periods for each animal, and ratios of 4 per cent milk per pound of dry matter have been computed.

These data are plotted in Figure I. Only a small difference in efficiency is noted between the two groups; however a decided decrease in efficiency with advance in lactation is evident in both groups. In order to relate this decrease in efficiency to the time of calving, the data were tabulated by 10 day periods and distributed according to the date of calving and the ratios for efficiency again computed. (Data relative to calving date are presented in Bulletin 169 of the Storrs Station.) These ratios of efficiency are plotted in Figure II. Decrease in efficiency with advance in lactation

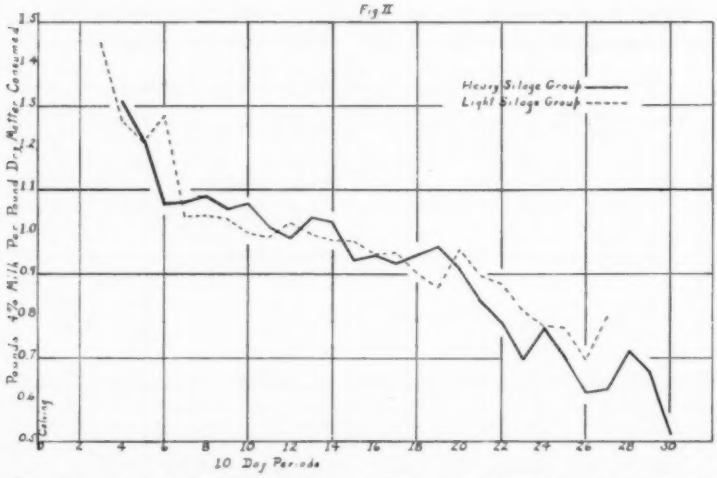


FIG. II. POUNDS OF 4 PER CENT MILK PRODUCED PER POUND OF DRY MATTER CONSUMED, PLOTTED ACCORDING TO THE LENGTH OF TIME AFTER CALVING.

becomes more pronounced when the data are plotted in this manner. The differences between the two groups are too meager and irregular to be significant with respect to type of ration. A study of the data from which Figure II was derived shows that not more than 8 animals are represented at any one 10 day period in the table, far too few numbers to establish a curve from which interpretations involving small differences may be made.

Eckles (5) gives data showing what percentage of the production of the maximum month of lactation is produced in succeeding months. When these data are plotted against the weighted averages of the 10-day periods of each month following calving for both groups collectively the relationship shown graphically in Figure III is obtained.

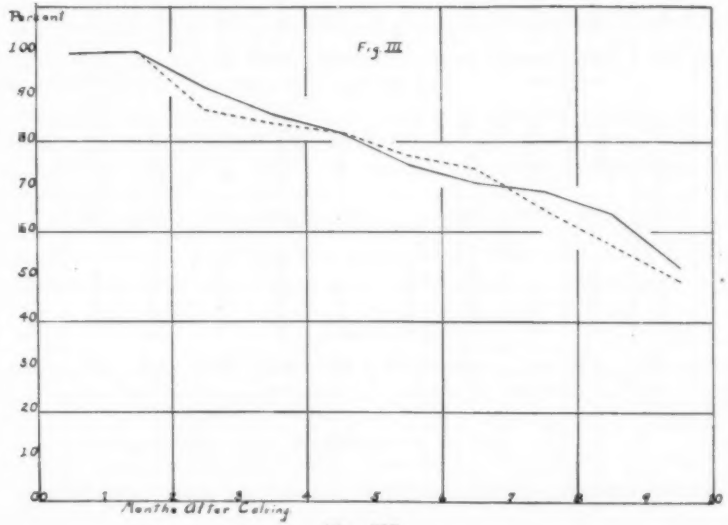


FIG. III.

Eckle's Data ———— Decline in Milk Production with Advance in Lactation.
Storr's Data - - - - - - - - Decline in Efficiency of Production with Advance in Lactation.

Error from this source was avoided as far as possible by carefully distributing the animals within the two groups with respect to stage of lactation.

It seems very probable that the decline in efficiency with advance in lactation is at least partially due to the increasing proportion of the dry matter consumption that is required for maintenance. The tendency manifested by all milking cows to lose weight in the early part of the lactation period and to regain it later has undoubtedly added to the decline in efficiency with advance in lactation. That decline in weight is comparatively small in this experiment is shown by the fact that the daily decline for the Heavy Silage Group was one twentieth of a pound per cow day and for the Light Silage Group one thirteenth pound.

Ratios of efficiency for individuals and groups for each feeding trial are shown in table 4. The data is concordant in showing a slightly greater efficiency for light silage feeding in each of the three trials in spite of

TABLE 4

Pounds of 4 per cent. milk produced per pound of dry matter in the ration

	HEAVY SILAGE GROUP						LIGHT SILAGE GROUP					
Trial I	Delight	Senora	Amiable	Sagacious		Group	Korndyke	Queen	Buoyant	Laureate		Group
	.926	.862	.888	1.105		.943	.808	.807	1.346	.991		.987
Trial II	Martha	Vanity	Genuine	Juniper		Group	Graceful	Secret	Poppy	Magnetic		Group
	.761	1.149	.595	.757		.847	.899	.946	.900	.820		.885
Trial III	Queen	Laureate	Secret	Jasmine	Favorite	Group	Korndyke	Amiable	Graceful	Tontine	Brilliant	Group
	.806	.877	.817	1.188	1.168	.955	.958	.837	.837	.941	1.153	.969
Weighted average of three trials						.925						.953

variations in quality of silage and hay and varying stages of lactation. It is evident from the wide variation in individual efficiency that drawing conclusions from small numbers and short experimental periods is not justified.

Reference to the body weights of the animals for the three feeding trials described (1) shows that collectively the Light Silage Group weighed 68 pounds more than the Heavy Silage Group. Since for the three trials the animals were on experiment an average of 88 days, the Therms of energy required for maintenance might be calculated and a correction be made. The maintenance requirement would be 36.32 Therms.

Further, since the weight changes of the two groups for the three trials collectively were 100 pounds in favor of the Heavy Silage Group a correction of 325 Therms should be made in its favor.

The algebraic sum of these two corrections would be 288.28 Therms in favor of the Heavy Silage Group. Since one pound of 4 per cent milk contains 0.336 Therms of energy this would equal 858.0 pounds of 4 per cent milk. If this amount be added to the corrected 4 per cent milk produced by the Heavy Silage Group for the three trials and the ratio of pounds of 4 per cent milk per pound of dry matter be calculated we find a ratio of 0.956 (that for the Light Silage Group was 0.953). Obviously,

this is within experimental error. Therefore, it must be concluded that there is no difference in efficiency in use of dry matter between the two groups.

SUMMARY

Experimental data are submitted to show the undesirability of short experimental periods and the dangers of the reversal type of experiment.

An analysis of the daily weights of a group of eight animals for a 100 day period shows that weighing three successive days of each 5 day period is practically as satisfactory as weighing daily.

Statistical analysis of morning and afternoon weighings shows that these animals averaged 16 pounds heavier at 8 A. M. than at 1 P. M. but shows no significant difference in probable error or percentage coefficients of variability at these hours.

The ratios of pounds of 4 per cent milk per pound of dry matter in the ration are given for individuals and for groups with advance in lactation. A marked decline in efficiency is shown with advance in lactation.

REFERENCES

(1) WHITE, GEORGE C., and PRATT, AVERY D. Optimum Amount of Silage in the Dairy Ration for Economical Production. Storrs Agri. Exp. Sta. Bul. 169. 1930.

(2) LUSH, J. L., CHRISTENSEN, F. W., WILSON, C. V., and BLACK, W. H. The Accuracy of Cattle Weights. Jour. Agri. Research, 36: 551. 1928.

(3) LUSH, J. L., and BLACK, W. H. How Much Accuracy is Gained by Weighing Cattle Three Days instead of One at the Beginning and End of Feeding Experiments? Am. Soc. Animal Prod. p. 206. 1925–26.

(4) GAINES, W. L., and DAVIDSON, F. A. Relation between Percentage Fat Content and Yield of Milk. Ill. Agri. Exp. Sta. Bul. 245. 1923.

(5) ECKLES, C. H. Dairy Cattle and Milk Production. p. 409. Macmillan Co., New York. 1923.

METHOD FOR OBTAINING REPRESENTATIVE SAMPLES OF BLOOD FOR INORGANIC PHOSPHORUS IN DAIRY HEIFERS[1]

H. O. HENDERSON

Department of Dairy Husbandry, West Virginia University

AND

A. H. VAN LANDINGHAM

Department of Agricultural Chemistry, West Virginia University, Morgantown, W. Va.

In recent years much study has been devoted to the inorganic phosphorus of the blood, because of its relation to various problems of nutrition, metabolism, and diseases.

Howard and Reay (4) report that the concentration of blood phosphorus is quite variable in human blood examined at hourly intervals. When the subject was changed from complete rest to ordinary movements about the laboratory, large fluctuations were observed. Robinson and Huffman (8) found a variation of inorganic phosphorus in blood of beef animals as high as 1.87 mg. per 100 ml. of plasma in 24 hours, and as much as 2.89 mg. during the 8 days during which daily determinations were made. Palmer, Cunningham, and Eckles (6) noted that blood phosphate in individual cattle may vary markedly from day to day even when the blood is drawn under apparently identical conditions. They also noted that the inorganic phosphate in individual cattle may vary from hour to hour. Certain physiological factors such as the ration (7), the ingestion of soluble carbohydrate (2), parturition (5), (8), (6), and exercise (6) have been shown to affect blood phosphate.

In early investigations of the inorganic phosphorus of the blood, single samples were used to obtain representative values for individual animals. Because the inorganic phosphorus of the blood is subject to day-to-day fluctuations, Palmer, Cunningham, and Eckles (6) and Henderson and Weakley (3) used the mean for three consecutive days as a representative phosphorus value.

In earlier work at this Station (3), when heifers were fed on both high and low-phosphorus rations, even though samples were taken on three consecutive days, marked variations were obtained from one determination to the next. These variations in blood composition led the authors to try to improve their method of sampling.

Received for publication December 4, 1931.

[1] Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 104.

EXPERIMENTAL

Samples of blood of about 15 ml. from the jugular veins of dairy heifers were collected in test-tubes containing 2.5 mg. of potassium oxalate per ml. as an anticoagulant. During warm weather the samples were immediately placed in crushed ice, carried to the refrigerator, and stored at 2° C. until analyzed for phosphorus. Analyses were made in most cases on the day the samples were taken; otherwise on the day following. All samples were taken at about 9 o'clock in the morning, approximately two hours after the heifers had been fed and watered. Inorganic phosphorus was determined on the oxalated blood by the method of Fiske and Subbarrow (1).

Daily Variations

The values plotted in figure 1 were obtained on 12 consecutive days on each of 8 animals. They show the extent to which the inorganic phosphorus may vary in 24 hours. It will be noted that a variation of 1.72 mg. per 100 ml. of blood occurred during 24 hours, and a variation as high as 2.34 mg. per 100 ml. of blood occurred during the 12 days in which daily determinations were made. The average daily variation for the 8 animals during the 12-day period was 0.46 mg. per 100 ml. of blood. It is possible that still greater variations may occur. Marked fluctuation from one day to the next is not unusual. However, in some instances a gradual rise was observed for a period of several days, followed by a slow decline. There seems, however, to be no consistency in the variations from one period to the next which might indicate cyclic or periodic fluctuations.

In order to obtain representative samples of blood the ideal method would be to sample several times daily for a period of several days. This procedure would require a considerable amount of time and might affect the animals adversely. When daily samples were taken for a prolonged period, knots and sensitive areas were developed above the jugular vein where the needle was inserted. This practice seemed to make the animals nervous and more easily excited. An attempt therefore was made to obtain a representative value of the inorganic phosphorus of the blood from the least number of samples and with the least possible disturbance of the animal.

When a study was made of the values obtained from daily sampling (Fig. 1) it was found that the mean of alternate-day sampling would check very closely with the mean of all 12 samples taken on 12 consecutive days, as shown in table 1. In this table are listed also values obtained for each three-consecutive-day period, as for the first three days, the second three days, etc. This was the method used at this Station in earlier work (3) and by other investigators (6). The deviations from the means of the 12-consecutive-day period shows that alternate-day sampling is much to be preferred over the values obtained for the three-consecutive-day periods.

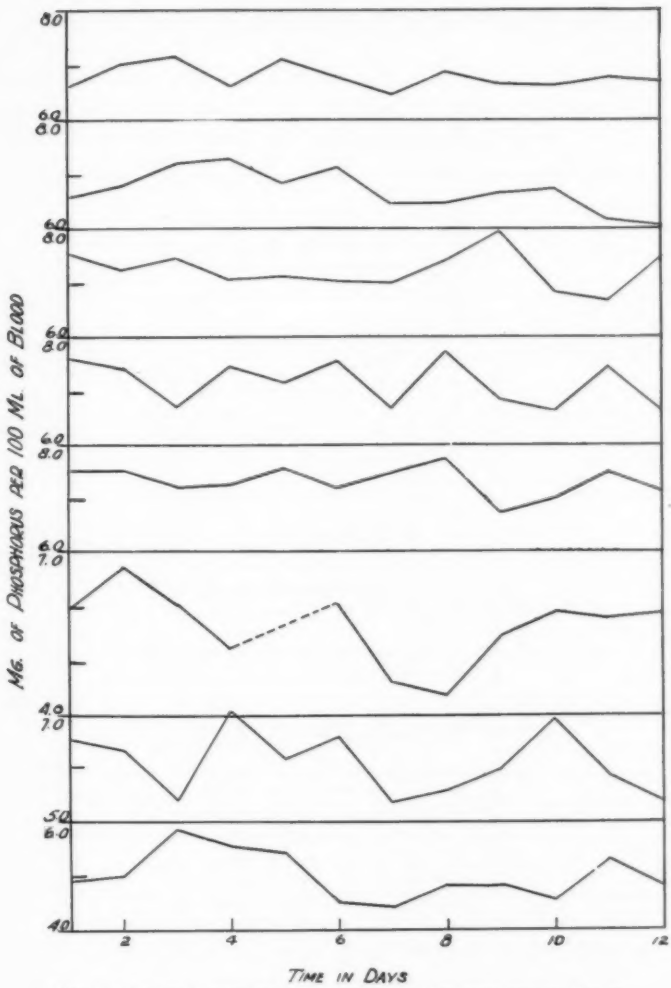


FIG. 1. DAILY VARIATIONS IN INORGANIC PHOSPHORUS OF BLOOD

Length of Storage Period

A study followed to determine the length of time the blood could be kept in storage and still give reliable results when analyzed for inorganic phosphorus. Suitable storage periods would provide for the possibility of obtaining a composite sample made up of a large number of individual samples on which a value might be obtained, which would be representative

TABLE 1

Milligrams of inorganic phosphorus per 100 ml. of blood

NUMBER OF ANIMALS	E35	E36	E37	E38	273	290	301	306	RANGE OF DERIVATION FROM 12-DAY MEAN (MGS.)
Means of:	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	
Twelve consecutive days	6.79	5.01	6.70	7.24	5.62	6.07	7.13	7.27	
Six alternate even days	6.80	5.13	6.66	7.30	5.56	5.86	7.00	7.29	−0.21 to +0.12
Six alternate odd days	6.79	4.89	6.74	7.17	5.67	6.29	7.22	7.27	−0.12 to +0.22
1st three days	6.94	5.25	6.87	7.44	6.11	6.06	7.22	7.37	−0.01 to +0.49
2nd " "	6.84	5.19	7.09	7.07	5.62	6.60	7.37	7.31	−0.17 to +0.53
3rd " "	6.96	4.70	6.51	7.44	4.80	5.61	7.06	7.28	−0.82 to +0.20
4th " "	6.71	4.90	6.32	6.99	5.83	6.02	6.88	7.15	−0.28 to +0.21

of the average content of that constituent in the blood of the individual animal.

Samples of about 200 ml. of blood were collected and divided into 15 aliquots of about 12 ml. each. The aliquots were stored in the refrigerator at 2° C. until they were analyzed for inorganic phosphorus.

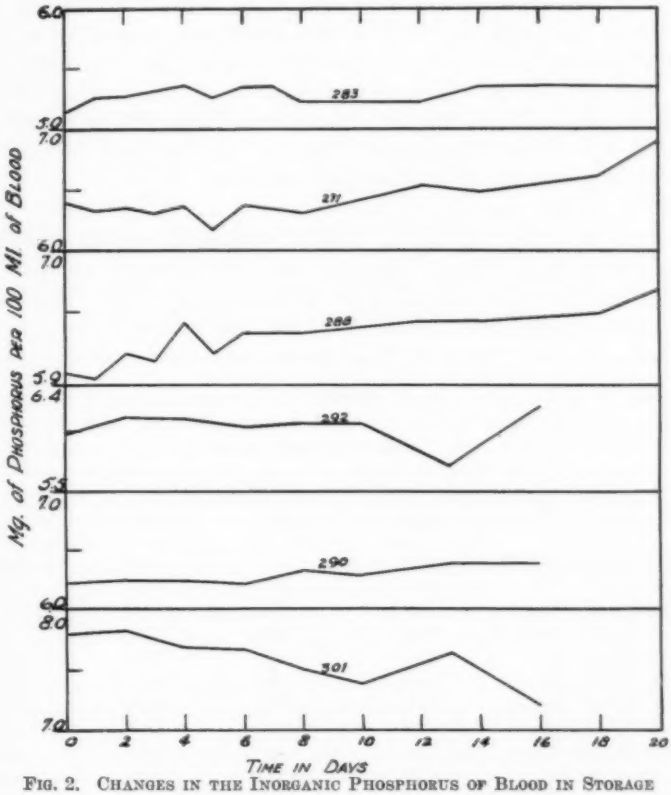


FIG. 2. CHANGES IN THE INORGANIC PHOSPHORUS OF BLOOD IN STORAGE

It may be noted from figure 2 that when these samples were analyzed there were no significant changes in the inorganic phosphorus until after a storage period of about two weeks. After a storage period of more than two weeks slightly higher values were obtained in most cases, due probably to decomposition of compounds containing phosphorus in organic combination.

From the data in figure 2 it was concluded that reliable values for inorganic phosphorus of blood in storage could be obtained after a storage period of two weeks.

Method of Obtaining Representative Samples

In order to obtain representative values for the inorganic phosphorus content of the blood for the individual animals, samples of blood of about 15 ml. were taken on alternate days for a period of 12 days. The samples were kept in storage at 2° C. until all six samples had been taken. They were then removed from the refrigerator and allowed to come to room temperature (about 20° C.). After the samples were thoroughly mixed by rotating the tube in such a way as to keep the blood from the mouth of the tubes, a composite sample of blood was prepared by taking 10 ml. from each of the six samples. This composite sample was thoroughly mixed by pouring from one beaker to another. Then it was analyzed for inorganic phosphorus by the method of Fiske and Subbarrow (1).

This procedure has been in use for several months in a study at this Station of the effect of feeding rations containing various amounts of phosphorus to dairy heifers. Samples have been taken on alternate days over a 12-day period during the first half of each month, and composites of these have been analyzed. No ill effects from the number of samples taken have been observed. In table 2 are listed some determinations made on

TABLE 2

Inorganic phosphorus in blood of normally fed animals (mg. of P. per 100 ml. of blood)

DATE OF SAMPLING	NUMBER OF ANIMAL			
	E35	E38	E39	E40
4 (14–24) '30	6.48	7.20	7.02	7.98
5 (12–22) '30	6.60	6.93	7.44	7.68
6 (2–12) '30	6.23	7.15	7.26	7.53
7 (1–11) '30	6.38	7.20	7.64	7.42
8 (2–12) '30	6.03	6.72	7.48	7.10
9 (2–13) '30	5.96	6.93	6.60	7.38
10 (7–17) '30	5.30	6.12	6.48	7.08
11 (4–14) '30	5.28	5.73	6.16	6.57
12 (2–12) '30	5.28	4.92	5.52	6.15
1 (6–16) '31	4.50	5.42	6.31	5.35
2 (3–13) '31	5.63	5.21	6.41	7.12
3 (3–13) '31	5.82	5.21	5.78	7.03
4 (3–13) '31	5.46	5.24	6.08	6.71
5 (4–14) '31	5.36	4.67	5.94	6.32
6 (3–13) '31	5.18	4.56	5.45	6.36
7 (2–12) '31	5.81	4.89	5.60	6.24

the blood of growing dairy heifers which were fed a normal ration. A certain amount of fluctuation from one month to another is noted, but with this method of sampling the variations are not nearly so great as have

been obtained from one day to another. The average monthly range in variation over a period of 16 months for the four animals (Table 2) is 0.35 mg. per 100 ml. of blood.

SUMMARY

The inorganic phosphorus content of the blood of dairy heifers was found to vary considerably from day to day. The average daily variation of eight dairy heifers was found to be 0.46 mg. per 100 ml. of blood for a 12-day period. However, a variation of 1.72 mg. per 100 ml. of blood for 24 hours occurred, and a variation as high as 2.34 mg. per 100 ml. of blood for the 12 days during which daily determinations were made was found.

Alternate-day sampling over a period of 12 days proved to be the most satisfactory method studied for obtaining a representative sample. The average monthly range in variation as determined by this procedure for four animals over a period of 16 months was found to be 0.35 mg. per 100 ml. of blood.

Storage of blood at 2° C. for 2 weeks was shown to have no significant effect on the amount of inorganic phosphorus found in the blood.

REFERENCES

(1) Fiske, C. H., and Subbarrow, Y. The colorimetric determination of phosphorus. Jour. Biol. Chem. **66**: 375. 1925.

(2) Harrop, G. A., Jr., and Benedict, E. M. The participation of inorganic substances in carbohydrate metabolism. Jour. Biol. Chem. **59**: 683. 1924.

(3) Henderson, H. O., and Weakley, C. E., Jr. The effect of feeding different amounts of calcium and phosphorus upon the growth and development of dairy animals. W. Va. Agr. Exp. Sta. Bul. 231. 1930.

(4) Howard, R. E., and Reay, G. A. Normal variations in the inorganic phosphate of the blood. Jour. Biochem. **19**: 822–887. 1925.

(5) Meigs, E. B., and Blatherwick, N. R. Calcium and phosphorus in the blood of lactating cows. Proc. Amer. Soc. Biol. Chem., in Jour. Biol. Chem. **29**: xi–xii. 1917.

(6) Palmer, L. S., Cunningham, W. S., and Eckles, C. H. Normal variations in the inorganic phosphorus of the blood of dairy cattle. Journal Dairy Science **13**: 174. 1930.

(7) Palmer, L. S., and Eckles, C. H. Effects of phosphorus-deficient rations on blood composition in cattle. Proc. Exp. Biol. and Med. **24**: 307–309. 1927.

(8) Robinson, C. S., and Huffman, C. E. Studies on the chemical composition of beef blood. (I) The concentration of certain constituents in normal beef plasma. Jour. Biol. Chem. **67**: 245. 1926.

THE COLI-AEROGENES DETERMINATION IN PASTEURIZATION CONTROL

M. H. McCRADY AND EM. LANGEVIN
Provincial Bureau of Health, Province of Quebec, Montreal, Canada

Central control of pasteurization of milk and cream involves three essential factors: supervision of design and installation of plant equipment, inspection of plant operation, and laboratory examination of the product at various stages of the processing. During the past few years particular attention has been directed, very properly, to reform in design of pasteurization equipment and to efficient inspection of plant operation, but this development has been attended by a peculiar neglect of the possible advantages to be derived from intensive laboratory control.

It is well-recognized that a weak link in processing milk may be the handling of the product as it passes from the pasteurizer to the final container. It is here that manual manipulation of piping and apparatus and exposure of the pasteurized product to contamination of insufficiently cleaned and sterilized equipment necessitates constant vigilance on the part of the operator to prevent conversion of the safe heated product to a recontaminated product which may become a vehicle of dangerous infection. Regular inspection of this stage of the processing is indispensable, for it frequently permits detection of defects accidentally developed in equipment and of bad habits in methods of operation.

Inspection alone, however, is not sufficient. It cannot, in routine practice, follow every detail of the cleaning and sterilizing operations, nor can it always be depended upon to detect every defect which may develop even in the best of equipment. Loose joints, fissures in metal linings, breaks in welded seams in which bacteria may lodge and multiply are probably frequently missed in routine inspection. For example, two experiences encountered during the course of the Montreal Milk Epidemic of 1927 may be recounted. Upon the occurrence of the second outbreak, or recrudescence, of the epidemic the Director of the Provincial Bureau of Health assumed the control of the milk plant held to be responsible, with one of the writers in charge of operation. Although every effort was being made to locate every possible defect in the equipment, it was not until several days of this control that a serious defect in the cooler was discovered. The soldered seam joining the metal sheeting a few inches above the bottom on the inside face of each curtain of the cooler buckled open slightly over a distance of several feet, whenever the curtain was moved. Samples taken from the pockets thus formed contained as many as 93 million bacteria and 100,000 coli per cc. It was the custom of the foreman of the pasteurizing

floor frequently to grasp the end of a curtain and pull it back in order to detect freezing of the milk on the coils. At every such movement of the curtain material was expressed from the open seam to be washed into the cooler basin. When it is considered that the foreman appointed to the pasteurizing floor a short time previous to the typhoid outbreak was found to be a typhoid carrier, that material from his hands was certain to be transferred to the inner face of the curtain to be washed over the open seam, the potential danger of this defect is manifest. If coli and other bacteria were multiplying in these pockets, it is probable that the typhoid bacillus also could multiply there. Steaming of the cooler, as ordinarily practiced, did not sterilize the pockets, for they were protected on the outside face of the curtains by the mass of metal in the angle iron of the bottom. Both steam and hypochlorite were employed freely at the time, the hypochlorite solution being passed through the whole equipment just ahead of the milk. Yet incubation of the bacteria in these pockets was proceeding apace.

Later, another defect was found. By this time routine laboratory control had been established, with coli-aerogenes tests included. The final product which was usually free from coli in 1 cc. quantities began to show the presence of coli in 1 cc. and occasionally in 0.1 cc. quantities. The plate counts, however, were normal. The cooler was again studied carefully, and it was finally found that, upon exerting pressure against one of the standards supporting the refrigerating coils, it rocked slightly upon its base. Another broken joint was revealed from which a small amount of material exuded whenever the standard was rocked by manipulation of the heavy metal curtains. Milk from the coils was continually flowing over this break, yet a pipette held at the joint collected a mixture of milk and material from the joint which contained 1,650,000 bacteria and 10,000 coli per cc. This mixture was being washed continually into the cooler basin. Immediately after the defect was remedied, coli disappeared from the final product.

One point is to be noted in connection with defects of this type: the washing powders used for cleansing the equipment and the attempts to sterilize the equipment may so alter the conditions as to induce variations in the predominating flora. Thus, in one of the open curtain seams described above, the contents on one day contained about 9 million bacteria and 100,000 coli per cc., the next day 93 million bacteria but no coli in 1 cc. As soon as the defect was discovered the curtains were moved back from the coils, so that the milk which might reach them could not flow into the cooler basin. They had been washed, partially steamed and treated with hypochlorite each day, and it was probably these operations which effected the remarkable variation in the flora of the liquid contents.

Recontamination of heated milk due to defects of the general character of those described is particularly dangerous because of its constant operation; it is only a question of time until the chance disease organism may become established, multiply and infect the product.

Recontamination due to insufficient cleaning and sterilization of equipment is an experience common to all who have had to do with control of pasteurization. Such recontamination is usually only intermittent in character, but is nevertheless potentially dangerous, because of the possibility of incubation of disease bacteria, derived from extraneous sources such as carriers, flies and other insects or from insufficiently heated milk, in the material left on the equipment.

In view of the menace presented by recontamination of pasteurized milk or cream it is rather surprising that so little effort has been made in recent years to exploit the possibilities of detection of such failure by laboratory means. The present Standard Methods of Examination of Milk published by the A. P. H. A. provides, as the only defense against this danger, the official plate count. Yet it must be obvious that, because of normal variations in the bacterial content of the final product due to several causes, such as variation in bacterial content and flora of the raw milk, and in the character of the processing, the residual bacterial count of some hundreds or thousands must be increased by further hundreds or thousands before the difference in comparative plate counts assumes significance. This means that large numbers of bacteria may be added to efficiently pasteurized milk through recontamination without any significant effect upon the plate count. Thus, while comparative plate counts may, at times, indicate gross recontamination, supplementary laboratory methods of greater sensitivity than that of the plate count are much to be desired.

THE COLI-AEROGENES DETERMINATION AS A SUPPLEMENTARY METHOD

The coli-aerogenes determination was first officially suggested in the Report of Committee on Milk Supply published by the American Public Health Association in 1920. That report laid down a rather complete program for control of pasteurization by means of this test, requiring absence of coli from 1 cc. portions during the processing. The suggestion apparently was not followed by the study and experimentation with the coli determination which reasonably might have been anticipated. During the past ten years little official notice has been given to this application of the coli test. Possibly the lack of a simple medium to replace lactose broth, which is notoriously unsuited to detection of coli in milk, was partly responsible for this indifference. Possibly undue emphasis on the fact that certain strains of the coli-aerogenes group may survive pasteurization temperatures served further to paralyze initiative in this direction. In any event, it was not until 1927 that Swenarton (1) following a study of

samples of pasteurized milk collected from bottling machines and the final container at plants in Baltimore, again seriously broached the subject of the coli determination as a control test, suggesting a maximum limit of 20 per cent of 0.1 cc. portions positive, and proposing a new medium, Gentian Violet Lactose Bile, to be used for the test.

When, following the Montreal Milk Epidemic of 1927, the Quebec Provincial Government conferred upon the Provincial Bureau of Health full control of pasteurization of milk and cream, a thorough investigation of the plants within the Province was instituted, one of us being detailed for this study. As the coli-aerogenes determination had been, for years, with the exception of a short interval, a routine feature of milk examination by the Provincial Laboratories, it was included in this investigation. The findings, as regards the applicability of this test to pasteurization control, were interesting.

Before proceeding to a detailed discussion of the results obtained, the laboratory method employed may be described. As lactose broth is not satisfactory for detection of coli-aerogenes in milk, Kessler and Swenarton (2) suggested the use of a special medium devised by them, Gentian Violet Bile, and showed that it was a reliable medium for the purpose. The Laboratories of the Provincial Bureau had employed the Brilliant Green Bile of Muer and Harris (3) and later had adopted the two per cent Brilliant Green Bile (4) proposed for water examination. To obtain a conception of the comparative value of the two media a series of 139 samples of bottled pasteurized milk was examined by means of both the Gentian Violet Bile and the two per cent Brilliant Green Bile (Digestive Ferments Company dehydrated products). The test involved the placing of 1 cc. of the undiluted milk in each of two Dunham fermentation-tubes; 2 drops (roughly 0.1 cc.) in each of two similar tubes; 1 cc. of the 1–100 dilution in the next two tubes; and finally, 2 drops of this dilution (roughly 0.001 cc.) in the last two tubes. The eight tubes were held together, as a unit, in a zinc box provided with a cover in which a strip of "eiderdown" served as a common cotton plug for all the tubes, the apparatus being identical with that described by one of us (5) for water examination. The appearance of gas after 48 hours on incubation at 37° C. was considered positive. The results of this comparative examination follow:—

	GENTIAN VIOLET BILE	BRILLIANT GREEN BILE
Number of samples examined	139	139
Identical negative results	84	84
Identical positive results	16	16
Results indicating more coli with one than with the other medium	18	21

The two sets of results agree very well. The results with the Brilliant Green Bile were somewhat more satisfactory in that anomalies, with positives in higher dilutions and negatives in lower dilutions, were less frequently encountered with this medium. In consequence, the Brilliant Green Bile (two per cent) was employed, by the method detailed above, in the work to be described.

RESULTS FROM PLANTS OUTSIDE THE CITY OF MONTREAL

Passing now to the results obtained from the investigation of pasteurization plants in the cities and towns of the Province, exclusive of the City of Montreal, it should be noted that this was the first detailed study of these plants which had been attempted and that, in consequence, the samples collected represented operation under practically uncontrolled conditions. The results obtained from the total of 40 plants are shown in table 1. The temperature of pasteurization observed in these plants ranged from 140° F. upward. About three-fourths of the plants were employing temperatures of 143–145° F. The holding period was in all cases 30 minutes.

The striking feature of these results is the absence of coli-aerogenes from the milk after it had been heated. In only two cases were organisms of this group present in one of the two 1 cc. portions examined; all the other results were negative. Apparently in none of these plants were heat-resistant coli a problem, at least at the time of this study. The plate counts of samples of the heated milk also were quite satisfactory. Thus, even under such uncontrolled conditions, these 40 plants were encountering no difficulty in obtaining reasonable plate counts and practical absence of coli-aerogenes from 1 cc. samples of the heated milk.

When the results from samples collected at further stages of the processing are considered, the picture is quite different. The proportion of 1 cc. samples containing coli increased from 3 per cent at the holder to 23 per cent at the cooler, to 42 per cent at the bottling machine, and to 36 per cent in the final container. Table 1 shows that these plants were practically all successful in their attempts to pasteurize the milk, but about half of them were recontaminating the heated milk in the course of the subsequent processing. In some cases the recontamination was indicated only by the plate count, but in others only by the coli-aerogenes determination.

Particular attention is invited to the consistency of the coli results as compared with the plate counts: the latter may vary greatly but the coli figures are usually maintained from stage to stage. The striking significance of the coli results, where positive, is also in marked contrast to the uncertain significance of many of the differences in plate counts. This is not surprising, for the plate count of the milk as it leaves the pasteurizer is, as a rule, a function of the raw milk count which may vary markedly

TABLE 1

Plate counts and presence of coli-aerogenes organisms in raw and pasteurized milk from small plants

PLATE COUNTS					COLI-AEROGENES*				
Raw	Pasteurized	Cooled	Bottler	Bottled	Raw	Pasteurized	Cooled	Bottler	Bottled
110,000	400	1,000	1,200	1,000	222–	——	211–	22—	22—
480,000	2,500	5,000	8,000	3,000	2221	——	21—	2——	2——
310,000	200	800	600	800	2222	——	1—	2221	2222
680,000	9,800	1,200	4,000	1,400	2222	——	——	221–	21—
270,000	18,000	15,000	7,800	7,000	22—	——	——	222–	2222
88,000	45,000	10,000	12,000	9,000	221–	——	1—	2——	21—
14,000	800	400	1,600	1,200	221–	——	2——	2——	1——
61,000	8,000	4,800	2,200	1,800	11—	——	——	2——	——
230,000	4,800	2,800	9,600	6,600	——	——	——	1—	22—
49,000	2,200	6,000	1,600	2,000	111–	——	2——	221–	22—
	3,200	7,600	63,000	23,000		——	222–	2211	2221
560,000	200	400	25,000	7,800	2212	——	2——	221–	221–
6,000,000	26,000	26,000	43,000	120,000	2222	1—	221–	222–	2221
1,400,000	6,800	13,000	53,000	25,000	2222	——	1—	221–	2211
6,000,000	13,000		62,000	22,000	2222	1—		2222	221–
14,000	200		3,200	800	——	——	——	2——	——
1,300,000	400	200	27,000	40,000	2222	All results negative			
110,000	2,600	3,800	14,000	4,800	221–				
75,000	3,000	1,000	17,000	13,000	2——				
140,000	6,600	13,000	34,000	32,000	221–				
18,000	1,000	400	48,000	36,000	2221				
530,000	4,200	200,000	19,000	17,000	221–				
140,000	200	200	18,000	200	2——				
1,200,000	1,600	2,400	6,000	3,200	221–				
130,000	400	600	2,000	600	21—				
220,000	1,200	500	1,000	2,500	22—				
8,200	200	200	600	200	11—				

* Coli-aerogenes:—2 portions examined of each of the following quantities:—1 cc., 0.1 cc., 0.01 cc., 0.001 cc.

The results are shown in this order. Thus, 21— signifies that coli-aerogenes organisms were found in both of the 1 cc. portions, in one of the 0.1 cc. portions and in none of the other portions.

The table includes results only from those plants where a sample at a stage subsequent to pasteurization gave a plate count greater than twice the count of the pasteurized milk, or positive coli results in at least two portions in excess of the number of portions of the pasteurized milk found positive.

as milks from different cans and from different producers are sent through the plant. In consequence, unless the sampler can be certain that he has followed the same batch of milk, not mixed with milk from previous runs, the significance of variation in the milk count from stage to stage in the processing is difficult to evaluate. Further, a difference of hundreds or thousands in counts may be well within the experimental error of results obtained from the usual method of obtaining such counts. On the other hand, the coli content of the milk as it leaves the pasteurizer is usually very low, and the addition of even a few coli during the subsequent processing can be readily detected.

From a consideration of this limited series of results the following observations are pertinent:—

Coli-aerogenes organisms were practically absent from 1 cc. quantities of the pasteurized milk.

Both coli-aerogenes determination and plate counts were necessary for the detection of recontamination.

Of the two methods the coli-aerogenes determination yielded the sharper, and therefore the more significant, as well as the more consistent results in those cases where the organisms were found.

RESULTS FROM MONTREAL CITY PLANTS

Considering now the larger plants supplying pasteurized milk to the City of Montreal, it must be remembered that the conditions under which they operate are rather different from those under which the smaller plants operate, in that the larger plants are usually adequately staffed, well equipped and favored with managements which are usually familiar with the principles involved in the production of safe pasteurized milk. As a consequence, these plants might be expected to turn out a product somewhat superior to that of the smaller plants.

It happens that two series of results of examination of samples of bottled pasteurized milk, picked up from delivery wagons of eight of the largest Montreal plants, are available for comparison. One series was obtained from 96 samples collected between the dates of March 14 and May 27, 1927, during the first stage of the Montreal Milk Epidemic, and examined by the Provincial Laboratories. These samples were taken at a time when the city was in the throes of an unprecedented outbreak of typhoid suspected to be due to infected milk. In consequence, the managements of these eight plants were exercising particular care to distribute a safe product and, so far as they could determine, were taking no chances.

The other series was obtained from 114 samples collected from wagons of these same eight plants in cities and towns adjacent to Montreal during the first six months of 1931.

The coli-aerogenes results obtained from the two series of samples are shown in table 2. (Two portions of each dilution of each sample were tested for gas formation in Brilliant Green Bile.)

TABLE 2

Plate counts and presence of coli-aerogenes organisms in raw and pasteurized milk from large plants

PLANT	NUMBER OF SAMPLES TESTED		PERCENTAGE OF 1 CC. PORTIONS CONTAINING COLI		PERCENTAGE OF 0.1 CC. PORTIONS CONTAINING COLI	
	1927–1931		1927–1931		1927–1931	
A	8	9	0	0	0	0
B	9	5	11	0	11	0
C	15	24	13	4	0	0
D	10	10	35	0	5	0
E	8	7	19	7	0	0
F	16	24	53	4	25	2
G	15	25	70	16	23	0
H	15	10	87	10	77	5

The milk regulations of the City of Montreal, throughout this time, have required a pasteurization temperature of 142 to 145° F. and a holding period of 30 minutes. There is reason to believe that most of the milk, represented by these samples, was subjected to temperatures approaching the upper of these limits.

It will be noted from table 2 that despite the peculiar circumstances obtaining at the time when the 1927 series of samples was collected, coli-aerogenes organisms were very frequently present in both 1 cc. and 0.1 cc. portions examined. All but one of these plants approached Swenarton's criterion of not over 20 per cent of 0.1 cc. samples positive.

The marked improvement in the results obtained from the 1931 series was due partly to improvement in equipment and partly to the efforts of the Division of Food Inspection of the City Department of Health. This division has waged a determined campaign to eliminate recontamination and, convinced of the value of the coli-aerogenes determination, has predicated its efforts largely upon the results obtained from this method of laboratory examination. As a consequence, whereas the percentage of plate counts of over 60,000 was reduced from 11 to 4, the percentage of 1 cc. portions containing coli was reduced from 42 to 6½, and the percentage of 0.1 cc. portions containing coli from 21 to less than 1.

These results show what can be done,—they show that coli can be practically eliminated from 1 cc. portions of bottled pasteurized milk as delivered to the consumer, that only one of these plants failed to reduce the coli content to a limit of 20 per 100 cc. of samples instead of the 200 per 100 cc. of Swenarton's suggested limit. The milk from three of these plants

contained no coli in 1 cc. upon examination of a total of 48 such samples from these plants.

CONCLUSIONS

From a consideration of these two series of results from large as well as from small plants, the following conclusions appear to be warranted:—

1. The plate count, as a laboratory method of pasteurization control, is not adequate. Supplementary laboratory methods are much to be desired.

2. Since organisms of the coli-aerogenes group are seldom found, as indicated by gas formation from 1 cc. quantities, in properly pasteurized milk; since the addition of even small numbers of coli added to such milk can be readily detected, and since coli readily become established and multiply in traces of milk in the more dangerous types of defects and on unsterilized surfaces of pasteurization equipment, the coli-aerogenes determination constitutes a reliable supplementary laboratory method of control.

3. Large city plants, and probably small plants as well, can deliver, to the consumer, milk which contains coli in not more than 10 to 20 per cent of the 1 cc. portions tested.

It should be noted that these conclusions are quite in accord with those indicated in the Report of the Committee on Milk Supply of 1919 to which reference has been made.

In view of the potential danger in recontamination of pasteurized milk and the inadequacy of inspection and the plate count to indicate every instance of recontamination it would appear desirable that, pending a search for other supplementary tests, Standard Methods of Milk Analysis include the coli-aerogenes determination as a supplementary method for collecting additional data on the condition of pasteurized milk.

REFERENCES

(1) SWENARTON, J. C. Can *B. coli* be used as an index of the proper pasteurization of milk? J. Bact. 13: 419. 1927.

(2) KESSLER, M. A., and SWENARTON, J. C. Gentian violet lactose pepton bile for the detection of *B. coli* in milk. J. Bact. 14: 47. 1927.

(3) MUER, T. C., and HARRIS, R. L. The value of brilliant green in eliminating errors due to anaerobes in the presumptive test for *B. coli*. Am. J. Pub. Health 10: 874. 1920.

(4) JORDAN, H. E. Brilliant green bile for the detection of the coli-aerogenes group. J. Am. Water Works Assoc. 18: 337. Sept., 1927.

(5) MCCRADY, M. H. The numerical interpretation of fermentation tube results. J. Inf. Dis. 17: 183. July, 1915.

THE HEAT COAGULATION OF MILK

1.—VARIATIONS IN THE COMPOSITIONS, HEAT STABILITY, AND OTHER TESTS OF MILKS FROM FOUR COWS DURING THE COURSE OF A LACTATION PERIOD

GEORGE E. HOLM, B. H. WEBB AND E. F. DEYSHER

Bureau of Dairy Industry, U. S. Department of Agriculture, Washington, D. C.

A knowledge of the factors that are responsible for the variations in the stability of milks to heat is of prime importance in the evaporated milk industry. At present the manufacturer is handicapped by the lack of information concerning the normal variations that may be expected. He is further handicapped by the lack of reliable tests whereby he can foretell the stability of an evaporated product from the behavior of the fresh milk from which it was manufactured. None of the various "rapid" tests which are at present in use—the alcohol test (1), (2), the acidity test (3), (4), the phosphate test (5)—has been found reliable for predicting the heat stability of all samples of evaporated milk.

The "salt balance" of milk, or the ratio of the sum of the gram equivalents of CaO and MgO to the sum of the gram equivalents of citric acid and P_2O_5, has been advanced by Sommer and Hart (6) as being of prime importance in determining its heat stability. These investigators believe (7) that the "salt balance" relationship can be most clearly demonstrated by very small additions of the appropriate salts and that such a procedure is more reliable than a determination of the salt balance by analytical methods as was done in their early work and also by Rogers, Deysher and Evans (8).

Sommer and Hart (9) (7) from their work on fresh whole milk found that "the demonstration that the milk salts have a decided effect upon the stability of the casein in fresh milk is quite conclusive" and further that "this logically leads to the conclusion that they must have a similar effect on the evaporated milk for we are dealing here with a system that is entirely similar, modified only to the extent to which it has been concentrated and the heat treatment and other manipulations it has undergone. This was readily demonstrated by the addition of these salts to concentrated milk both on an experimental scale and under commercial conditions."

This position is not substantiated in later work reported by these authors (7). They state that "with evaporated milk no case has been found where the coagulation was due to a lack of calcium. Even milk samples that in the unconcentrated form showed coagulation in the heat test, on account

Received for publication December 10, 1931.

of lack of calcium, when concentrated as for evaporated milk, evidence no such lack of calcium."

The purpose of this part of the investigation has been to determine to what extent compositions, different heat stability tests and other tests commonly employed, of milk from four cows throughout a lactation period, correlate with time of coagulation by heat of both the fresh and evaporated products.

EXPERIMENTAL

Four cows were selected from the herd of the Bureau of Dairy Industry at Beltsville, Maryland. The cows all calved in October, 1928, within a ten-day period. Cows Nos. 811, 813 and 815 were Holsteins, while cow 659 was a Jersey. The feed of the cows, during the period that the milk was examined, was the same and consisted only of grain, hay, silage, and beet pulp. The cows did not receive pasture at any time during the period of November 1, 1928, to November 1, 1929, with the exception that Cow 813 was turned on pasture October 26, 1929.

Twenty-four hour samples of the milk from each cow were examined within four hours after the morning milking. Tests and analyses of the milk were made each month throughout the lactation period, except during the months of June and July.

The tests and analyses which were conducted upon the samples of milks were the following: total solids, fat, ash, calcium, magnesium, phosphorus, citric acid, titratable acidity, H-ion concentration (pH), alcohol, phosphate, buffer intensities and the time of coagulation of the raw milks by rennet and by heat and of their evaporated samples by heat.

The total solids were determined by drying a sample at 100° C. and weighing the dry matter. Fat percentages were obtained by the Babcock test, and the solids-not-fat percentages represent the difference between the fat and total solids.

The titratable acidity is expressed as percentage lactic acid, the titration having been made with N/10 NaOH, with phenolphthalein as the indicator. The H-ion concentration is expressed as pH and was determined potentiometrically with a quinhydrone electrode.

The alcohol test was carried out with 68 per cent alcohol by volume. The test was considered as positive or negative depending upon the presence or absence of coagulation when 2 cc. of alcohol was added to 2 cc. of milk. The phosphate test (5) is expressed as 10 × the number of cc. of M/5 KH_2PO_4 required to coagulate 10 cc. of fresh milk, after the mixture has been placed in a test-tube and immersed in boiling water for five minutes.

Coagulation tests were made upon the unevaporated milk by the use of rennet and by heat, and upon the evaporated milk by heat. Powdered rennet of a strength of 1: 30,000 (Eimer and Amend) was made up into fresh solutions for each series of monthly tests by dissolving 0.5 gr. of

rennet in 200 cc. of distilled water. Five cc. of rennet solution was added to 230 cc. of the warm milk in a bottle at 37° C. The milk was quickly mixed and placed in a 37° C. water bath. The time of coagulation was determined by observing the time of flow of a fine stream of milk siphoned out of the bottle by means of a capillary tube. The limit of error for the time of rennet coagulation was ± 0.1 minute. The time of heat coagulation of the milk was determined by holding the canned milk in a pilot sterilizer and withdrawing the cans at intervals to note the time required to bring about coagulation. Fifteen minutes were allowed to bring the milk up to the sterilization temperature. The unevaporated milk was held at 130° C. until it coagulated and the evaporated milk, which was forewarmed to 95° C. for 10 minutes before evaporation to 18 per cent solids-not-fat, under 26 inches of vacuum, was sterilized at 118° C.

The salt analyses were made as follows: Calcium and magnesium were determined by McCrudden's method (10). The P_2O_5 was determined gravimetrically as $Mg_2P_2O_7$, according to the method of the Association of Official Agricultural Chemists (11). Citric acid was determined by Beau's titration method (12). Recent investigations in this laboratory indicate that this method as used here yields results which are probably somewhat too high. However, the values given are entirely comparable among themselves and hence are valid for all comparative purposes.

The excess base was calculated according to Sommer and Hart's method (6). The percentages of each salt were converted into gram equivalents as follows:

$$(a)\ \frac{\text{citric acid} \times 100}{192}$$

$$(b)\ \frac{P_2O_5 \times 100}{71} \times \frac{7}{11}$$

$$(c)\ \frac{CaO \times 100}{56}$$

$$(d)\ \frac{MgO \times 100}{40}$$

The excess base figure is obtained by subtracting the gram equivalents of (Citric acid + P_2O_5) from those of (CaO + MgO).

The buffer intensity of each milk was investigated according to the methods used by Whittier (13). The change in pH was determined over the range from the original pH to pH 4.7. The average dB/dpH was calculated over this pH range. The average buffer intensity divided by the percentage of milk-solids-not-fat gives the average buffer intensity per gram and is reported as Av. dB/dpH / % S.N.F.

The results of the tests and analyses conducted upon the milk of the four cows throughout the course of a lactation period are shown in Tables

TABLE 1

Results of tests and analyses of samples of milk from Cow 659 at intervals during the course of a lactation period

Cow 659—Calved Oct. 17, 1928. Last milked Oct. 29, 1929. Total milk production 8,983.6 lbs.—Total butterfat production 482.82 lbs.

TESTS AND ANALYSIS	DEC. 3	DEC. 10	JAN. 14	FEB. 11	MAR. 18	APR. 22	MAY 13	AUG. 12	AUG. 19	SEPT. 23	OCT. 14
Total solids %	14.93	14.69	15.38	15.99	15.89	15.69	15.58	15.50	15.36	16.19	16.13
Fat %	4.70	4.55	5.10	5.50	5.40	5.50	5.35	5.20	5.20	6.00	5.80
S.N.F. (by dif.) %	10.23	10.14	10.28	10.49	10.49	10.19	10.23	10.30	10.16	10.19	10.33
Titratable acidity	.240	.277	.225	.245	.240	.220	.220	.180	.160	.170	.170
pH	6.54	6.57	6.52	6.55	6.60	6.50	6.70				
Heat stability tests											
Alcohol test	–	–	–	–	–	–	–	–	–	–	–
Phosphate test	21	21	22	21	22	22	22				
Coagulation time (minutes)											
By rennet 37° C.		13.60	14.05	13.22	13.20	12.90	17.00				
By heat (Unevap.) 130° C.	30+	38	45	31	54	42	50	27	26	38	45
By heat coag. (18% S.N.F.) 118° C.	18	42	25	16	15	18	17	17	25	22	34
Salt analyses											
Ash %	.78	.76	.74	.785	.77	.749	.755		.78	.746	.746
CaO %	.204	.198	.198	.202	.196	.186	.186		.185	.189	.187
MgO %	.025	.024	.023	.025	.025	.027	.025		.027	.026	.025
P_2O_5 %	.282	.267	.270	.284	.283	.265	.269		.268	.266	.268
Citric acid %	.280	.290	.251	.264	.22	.24	.25		.22	.22	.205
Excess base											
Gram equivalent of (Ca + MgO) – (Citric acid + P_2O_5)	.27	.23	.38	.30	.43	.36	.23		.42	.47	.49
Buffer capacity = dB/dpH from riginal pH to pH 4. 7											
Av. $\frac{dB}{dpH}$	.0275	.0271	.0274	.0277	.0286	.0280	.0254				
Av. $\frac{dB}{dpH}$/% S.N.F.	.00269	.00267	.00266	.00264	.00273	.00277	.00248				

TABLE 2

Results of tests and analyses of samples of milk from Cow 811 at intervals during the course of a lactation period

Cow 811—Calved Oct. 11, 1928. Last milked Oct. 4, 1929. Total milk production 10,681.6 lbs.—Total butterfat production 359.40 lbs.

TESTS AND ANALYSES	DEC. 3	DEC. 10	JAN. 14	FEB. 11	MAR. 18	APR. 22	MAY 13	AUG. 12	AUG. 19	SEPT. 23
Total solids %	11.71	11.77	12.08	11.81	12.14	11.77	11.73	12.73	13.04	
Fat %	3.00	3.00	2.95	3.00	3.20	2.85	3.10	3.50	3.45	
S.N.F. (by dif.) %	8.71	8.77	9.13	8.81	8.94	8.92	8.63	9.23	9.59	
Titratable acidity	.190	.180	.180	.170	.175	.170	.160	.160	.160	
pH	6.60	6.63	6.60	6.65	6.67	6.63	6.59			
Heat stability tests										
Alcohol test	–	–	–	–	–	–	–			
Phosphate test	18	16	16	16	15	14	13			
Coagulation time (minutes)										
By rennet 37° C.		14.05	15.25	18.24	15.88	15.97	18.20			
By heat (Unevap.) 130° C.	26+	33	32	42	40	46	30	28	20	
By heat coag. (18% S.N.F.) 118° C.	14	40	23	20	40	45	45	43	27	
Salt analysis										
Ash %	.74	.72	.72	.725	.73	.73	.737		.79	.91
CaO %	.160	.155	.158	.159	.157	.159	.154		.201	.233
MgO %	.023	.019	.022	.021	.023	.024	.024		.028	.027
P_2O_5 %	.216	.212	.210	.201	.203	.196	.192		.217	.242
Citric acid %	.28	.26	.28	.285	.26	.26	.260		.27	.19
Excess base Gram equivalent of (CaO + MgO) – (Citric acid + P_2O_5)	.04	.00	.03	.07	.20	.31	.28		.84	1.67
Buffer capacity = dB/dpH from original pH to pH 4.7										
Av. $\frac{dB}{dpH}$	.0217	.0212	.0214	.0208	.0214	.0221	.0210			
Av. $\frac{dB}{dpH}$ / % S.N.F.	.00249	.00242	.00234	.00236	.00240	.00248	.00235			

TABLE 3

Results of tests and analyses of samples of milk from Cow 813 at intervals during the course of a lactation period

Cow 813—Calved Oct. 21, 1928. (Aborted Nov. 14, 1929.) Last milked July 28, 1930. Total milk production 17,232.5 lbs. Total butterfat production 588.20 lbs.

TEST AND ANALYSES	DEC. 3	DEC. 10	JAN. 14	FEB. 11	MAR. 18	APR. 22	MAY 13	AUG. 12	AUG. 19	SEPT. 23	OCT. 14	OCT. 28
Total solids %	11.93	12.61	12.30	12.00	12.30	12.12	12.22	11.90	12.01	12.99	13.03	13.45
Fat %	3.00	3.75	3.20	3.00	3.10	3.45	3.55	3.20	3.20	3.50	3.85	4.00
S.N.F. (by dif.) %	8.93	8.86	9.10	9.00	9.20	8.67	8.67	8.70	8.81	9.49	9.18	9.45
Titratable acidity	.195	.195	.185	.185	.205	.160	.160	.150	.150	.160	.170	.140
pH	6.56	6.56	6.59	6.61	6.67	6.70	6.71					6.60
Heat stability tests												
Alcohol test	–	–	–	–	–	–	–	–	–	–	–	–
Phosphate test	15	14	15	15	15	14	14					5
Coagulation time (minutes)												
By rennet 37° C.		11.50	13.25	15.62	15.00	21.40	14.40					
By heat (Unevap.) 130° C.	8	8	7	7	5	35		24	35+	40	50	42
By heat coag. (18% S.N.F.) 118° C.	17	25	15	10	12	15		25	25	18	18	26
Salt analyses												
Ash %	.71	.70	.69	.71	.72	.69	.678		.70	.706	.737	.756
CaO %	.150	.155	.155	.156	.160	.149	.146		.156	.164	.184	
MgO %	.02	.020	.020	.021	.021	.023	.020		.024	.023	.022	
P_2O_5 %	.225	.218	.216	.219	.219	.194	.201		.183	.203	.222	
Citric acid %	.235	.245	.240	.247	.240	.250	.22		.25	.22	.237	
Excess base Gram equivalent of (CaO + MgO) – (Citric acid + P_2O_5)	– .06	.04	.08	.06	.17	.19	.16		.45	.54	.61	
Buffer capacity = dB/dpH from original pH to pH 4.7												
Av. $\frac{dB}{dpH}$	.0209	.0204	.0209	.0213	.0220	.0210	.0200					.02587
Av. $\frac{dB}{dpH}$/% S.N.F.	.00234	.00230	.00230	.00237	.00239	.00242	.00231					.00274

TABLE 4

Results of tests and analyses of samples of milk from Cow 815 at intervals during the course of a lactation period

Cow 815—Calved Oct. 17, 1928. Last milked Dec. 20, 1929. Total milk production 21,175.8 lbs.—Total butterfat production 695.27 lbs.

TEST AND ANALYSES	DEC. 3	DEC. 10	JAN. 14	FEB. 11	MAR. 18	APR. 22	MAY 13	AUG. 12	AUG. 19	SEPT. 23	OCT. 14	OCT. 28	NOV. 5
Total solids %	11.64	11.69	11.29	11.89	11.88	11.54	11.66	11.60	11.60	12.49	13.02	14.31	13.90
Fat %	3.40	3.50	2.80	3.30	3.20	2.95	3.10	3.00	3.05	3.50	3.80	3.97	4.40
S.N.F. (by dif.) %	8.24	8.19	8.49	8.59	8.68	8.59	8.56	8.60	8.55	8.99	9.22	10.34	9.50
Titratable acidity	.155	.160	.160	.175	.178	.160	.150		.160	.170	.160	.150	.140
pH	6.66	6.65	6.62	6.67	6.72	6.61	6.68					6.72	6.69
Heat stability tests													
Alcohol test	–	–	–	–	–	–	–		–	–	–	+	–
Phosphate test	13	12	13	13	12	11	11					7	8
Coagulation time (minutes)													
By rennet 37° C.		24.15	21.02	19.40	22.70	21.30	26.10						
By heat (Unevap.) 130° C.	4	6	5	5	4	9	5		31+	35	43		31
By heat coag. (18% S.N.F.) 118° C.	12	23	12	9	16	25	19		20	20	22		13
Salt analyses													
Ash %	.70	.70	.70	.69	.72	.72	.72		.72	.73	.763		
CaO %	.135	.134	.147	.144	.152	.147	.151		.148	.165	.176		
MgO %	.020	.018	.021	.020	.021	.025	.023		.023	.024	.025		
P_2O_5 %	.185	.182	.181	.183	.188	.183	.184		.178	.188	.196		
Citric acid %	.270	.261	.260	.267	.280	.277	.26		.26	.25	.261		
Excess base Gram equivalent of (CaO + MgO) – (Citric acid + P_2O_5)	–.16	–.15	.18	.04	.09	.16	.27		.26	.56	.65		
Buffer capacity = dB/dpH from original pH to pH 4.7													
Av. $\frac{dB}{dpH}$	.0183	.0199	.0196	.0187	.0201	.0210	.0199					.0288	
Av. $\frac{dB}{dpH}$/% S.N.F.	.00224	.00243	.00220	.00221	.00232	.00244	.00233					.00278	

1, 2, 3, and 4. A study of these tables will show that in many cases there is poor correlation among tests which according to the results of former investigators, should show better agreement. The data reported here have been plotted in many different ways in an attempt to analyze and interpret the results. Where reasonably consistent results have been found, figures have been drawn and are included.

There is a noticeable tendency for the total solids and fat percentages to increase as the lactation period progresses. This is in accordance with the normal trend for the milk of most cows.

The variations in titratable acidity and pH did not show any relation to the variations in heat stability of the milks.

The results of the heat stability tests commonly used did not correlate well with the time of heat coagulation of the milks. All four cows consistently produced alcohol negative milk. The phosphate test showed a tendency to decrease as the lactation period progressed, which would appear to indicate that the milk was becoming less stable to additions of hydrogen or calcium ions, but could perhaps be increased in heat stability by the addition of phosphate or citrate.

Ramsdell, Johnson & Evans (5) have recently been able to show a fair degree of correlation between the phosphate number of a milk and the heat stability of its evaporated product. These investigators worked with composite samples of herd milk, however. In the present investigation the milks of individual cows each showed a characteristic phosphate number which did not vary greatly with variations in the heat stability of each milk.

No relationship was found between the time of rennet coagulation and the time of heat coagulation of the different milks. If the time of rennet coagulation is plotted against the excess base no consistent relationship is observed. However, there is a tendency toward a shortening of the time of rennet coagulation as the calcium content of the milks increases, but this tendency is not very marked. Nor was there a tendency for the time of rennet coagulation to vary regularly with the changes in H-ion concentration of the samples of each milk, although the stabilities of the milks from various cows to rennet seemed to bear an inverse relationship to their characteristic H-ion concentrations.

The time of heat coagulation of the unevaporated and of the evaporated milks have been plotted against the time in the lactation period at which they were produced. A study of Fig. 1 will show that it is difficult to interpret this data in any positive manner. It can not be stated, except in the case of Cow 815, that there is any definite relationship between the time of coagulation of the samples of fresh milks and samples of their evaporated products. In most cases the heat stabilities of the milks tended to increase as the lactation period progressed until a maximum was reached

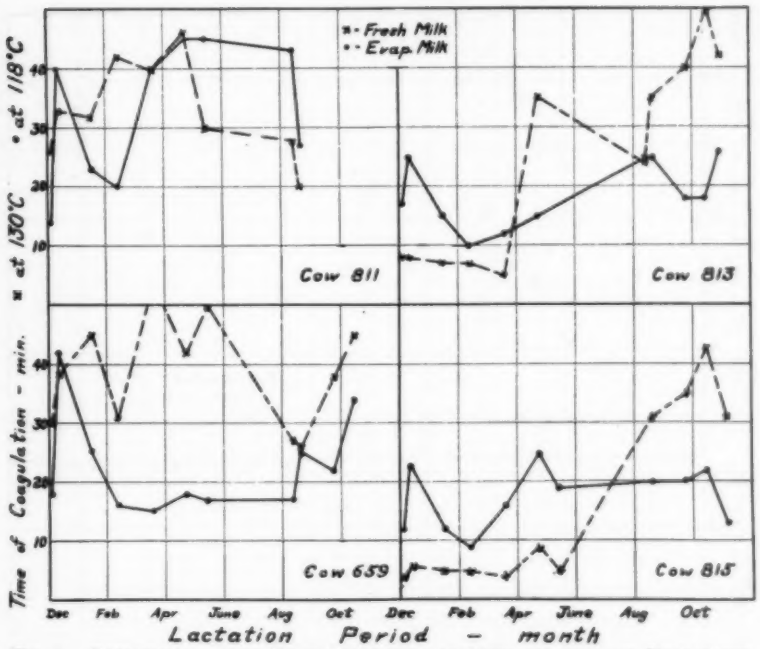

Fresh Milk
Evap. Milk
Time of Coagulation - min. • at 118°C × at 130°C
Cow 811
Cow 813
Cow 659
Cow 815
Dec Feb Apr June Aug Oct Dec Feb Apr June Aug Oct
Lactation Period - month

FIG. 1. VARIATIONS IN THE HEAT STABILITIES OF UNEVAPORATED AND EVAPORATED MILKS OF FOUR COWS AT INTERVALS DURING THE COURSE OF A LACTATION PERIOD

in April, when a decrease set in and finally a new maximum in stability was established toward the end of the period, this point being then followed in most cases by a final drop in the time of heat coagulation. Since the feed of the cows remained unchanged during the entire period, these variations can not be ascribed to the effect of green pasture or of other changes in diet.

According to the work of Sommer and Hart (6) there should be a good correlation between the time of heat coagulation of milks and their salt balance. The relationships found between the heat stability and the excess base in the milks examined here are shown in figure 2. The correlation is not good but it can perhaps be said that there is a tendency for the heat stability of these milks to increase as their calcium and magnesium content becomes greater. This is in direct contradiction to the results of Sommer and Hart (6) summarized by their statement, "Those that coagulated had the largest excess of calcium and magnesium."

The effect noted is more pronounced in the case of the fresh milks than in that of the evaporated samples.

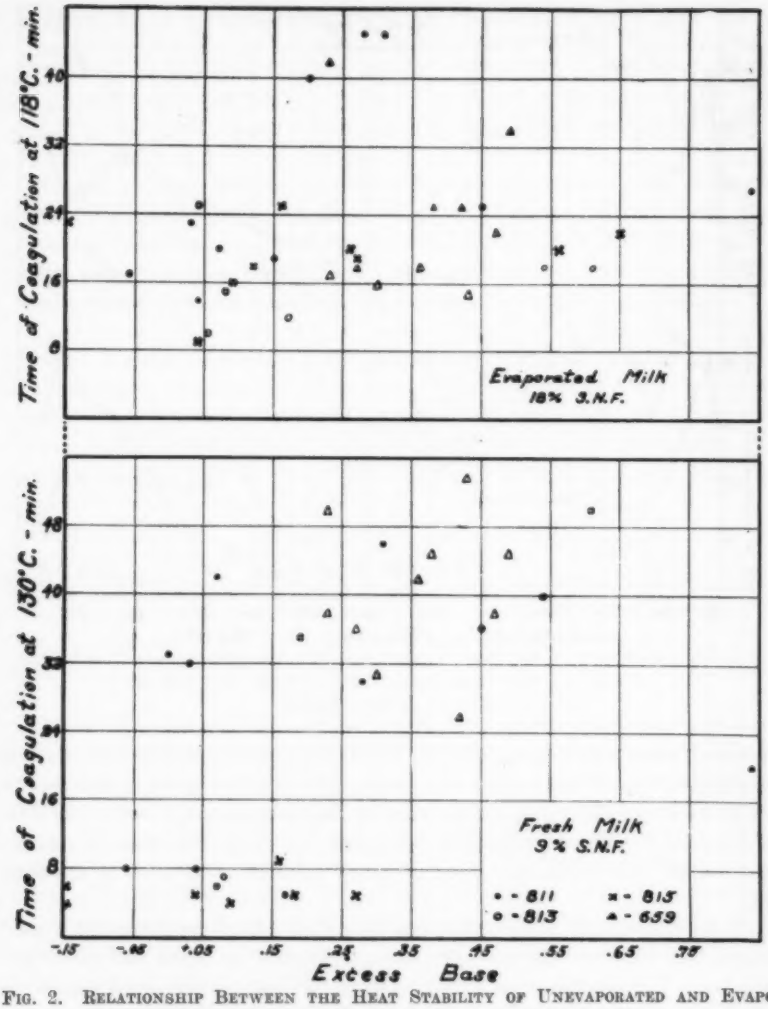


FIG. 2. RELATIONSHIP BETWEEN THE HEAT STABILITY OF UNEVAPORATED AND EVAPORATED MILKS AND THE EXCESS BASE OF THE ORIGINAL MILK

If the excess base is plotted against the time of lactation, a gradual increase is observed as the period progresses. However, a number of irregularities may be noted in such a figure.

Each milk had a characteristic buffer intensity curve which, although it varied to some extent, still retained its individuality when it was compared with the curves of other milks. Only the average buffer intensity

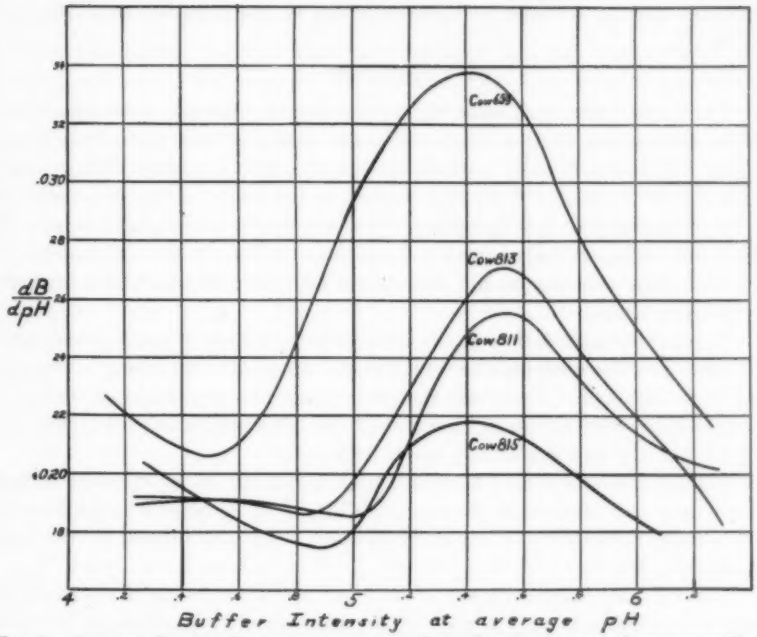


FIG. 3. AVERAGE BUFFER INTENSITIES OF THE FOUR MILKS, OVER A RANGE OF pH OF APPROXIMATELY 4.2–6.2, ON DECEMBER 10

data has been reported but figure 3 shows the buffer intensity curves of the four milks studied, as they were on December 10. There is a marked contrast between that for the milk from Jersey Cow 659 and that for the milk from Holstein Cow 815 in respect to the buffer capacity of their milks. The milk of the Jersey cow is typical of milk secreted by cows of this breed but the milk from Cow 815 is somewhat lower in buffer capacity than is normal Holstein milk. Maximum buffering occurs in each case between pH 5.4–5.6.

When the average buffer capacity of each milk is divided by its percentage of solids-not-fat, the resulting figure, the average buffer intensity per gram of solids, shows uniform variations with advances in the lactation period. From the figure obtained for early December a drop occurs to a minimum point in January or February. A gradual rise in dB/dpH / % S.N.F. now sets in until a maximum is reached in April, at which time a maximum in heat stability occurred also, as was previously shown. At this time there is an abrupt drop in buffer intensity up to the middle of May, after which time these measurements were discontinued except for two final figures obtained at the end of the period which show the milks

probably greatly increase in their buffering as the lactation time draws to a close.

DISCUSSION

The great variations observed in the results obtained with these four milks emphasizes what a wide difference exists in the properties of the milks. It does not seem improbable that the two extremes which would normally be encountered are represented by the milks of cows 659 and 815.

During the first few months of this experiment a composite sample of these four milks was also examined but since it did not show as much consistency in its behavior as did the individual milks, the composite analyses were discontinued.

The lack of correlation in the data presented here is much more striking than the few instances in which some degree of consistency in results has been obtained. The work does not strengthen any existing theory of heat stability but rather it shows that the correlations necessary for the support of any existing theory are lacking.

The early contention of Rogers, Deysher and Evans, as opposed to that of Sommer and Hart, that the heat stability of an evaporated milk bore no relation to the stability of the original fresh milk is confirmed by the data presented here.

That the salt balance theory of Sommer and Hart, while it does hold in some cases, explains only a part of the heat stability phenomena in milk, is conclusively shown by the results of the analyses given above. Many milks with a salt balance favorable to maximum stability as interpreted by them failed entirely to exhibit such a characteristic. Sommer and Hart have pointed out, that the salt balance can be shifted by amounts of salt well within the limit of error of analytical determinations. It does seem possible nevertheless, that such analyses would bear some relation to the heat stability of a milk if there were no other important factor controlling stability than salt balance.

The results of this study of the milks of individual cows serves to further emphasize the complexity of the problem of heat coagulation in milk. While the results are essentially negative in that they do not strengthen any existing views on the subject, yet they have a very positive value. The data show where correlations do not exist.

The conclusions of Benton and Albery (2) that for each milk there is an optimum combination of pH and salt balance which will give maximum stability is further emphasized by these results. "This optimum is probably the resultant of several variables and consequently is an expression of the colloidal peculiarities of the particular sample." Obviously there are other as yet unknown factors influencing the process of coagulation of milk by heat.

SUMMARY

The relationship between the heat stability and the composition and other properties of the milks of four cows during the course of a lactation period was investigated. No marked correlation was found between the heat stability and the various tests and analyses conducted upon the milks. The "rapid" tests sometimes used to classify milks to be used for condensing, such as the acid test, the alcohol test, and the phosphate test, did not satisfactorily indicate the relative heat stability of the milks. The salt balance as determined by analyses of the milks showed no direct correlation with the heat stability of the samples. The buffer intensity was not related to the stability of the milks toward heat. No clear relationship was noted between the heat stabilities of the fresh milks and of their evaporated products. Each of the individual milks for the most part retained fairly constant values in many of the tests, these values being characteristic of the milk from each cow.

The results of this investigation of the individual milks of four cows conclusively demonstrated the inadequacy of our present knowledge of the heat stability of milk.

REFERENCES

(1) DAHLBERG, A. O., and GARNER, H. S. Alcohol test for grading milk in condenseries. U. S. D. A. Bull. 944. 1921.

(2) BENTON, A. G., and ALBERY, H. G. Studies on the stability of evaporated milk during sterilization. J. Biol. Chem. **68**: 251. 1926.

(3) SOMMER, H. H., and HART, E. B. Grading milk by the acid test; influence of acids in the ration on the acidity of milk. JOURNAL DAIRY SCIENCE **4**: 7. 1921.

(4) FLEMING, R. S., and NAIR, J. B. The value of a titration test for acidity at the receiving platform. JOURNAL DAIRY SCIENCE **4**: 536. 1921.

(5) RAMSDELL, G. A., JOHNSON, W. T., JR., and EVANS, F. R. A test for the detection of milk unstable to heat. JOURNAL DAIRY SCIENCE **14**: 93. 1931.

(6) SOMMER, H. H., and HART, E. B. The heat coagulation of milk. J. Biol. Chem. **40**: 137. 1919.

(7) SOMMER, H. H., and HART, E. B. Heat coagulation of evaporated milk. Research Bull. 67 (1926) Wis. Agr. Exp. Sta.

(8) ROGERS, L. A., DEYSHER, E. F., and EVANS, F. R. The relation of acidity to the coagulation temperature of evaporated milk. JOURNAL DAIRY SCIENCE **4**: 294. 1921.

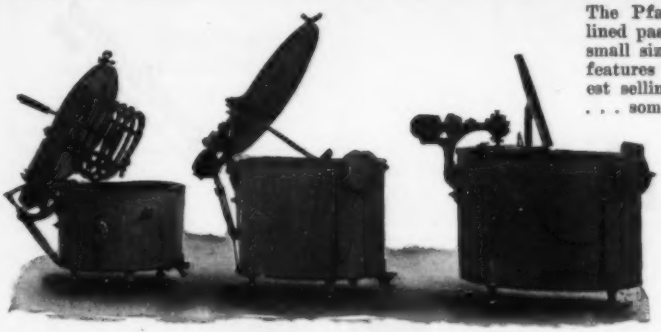
(9) SOMMER, H. H., and HART, E. B. The heat coagulation of milk. JOURNAL DAIRY SCIENCE **5**: 525. 1922.

(10) MCCRUDDEN, F. H. The quantitative separation of calcium and magnesium in the presence of phosphates and small amounts of iron devised especially for the analysis of foods, urine and feces. J. Biol. Chem. **7**: 83. 1909.

(11) Association of Official Agr. Chemists. Methods of Analysis, 2nd Ed. Rev. p. 2. 1925.

(12) BARTHEL, C. Methods used in the examination of milk and dairy products. Trans. by W. Goodwin, p. 91. 1910.

(13) WHITTIER, E. O. Buffer intensities of milk and milk constituents. I. The buffer action of casein in milk. J. Biol. Chem. **83**: 79. 1929.



100-gallon Lo-Vat equipped with heating or cooling coil suspended from screw-elevated cover. With coil Lo-Vat makes an ideal cream ripening tank.

200-gallon model with one-piece counter-balanced cover. Agitator and thermometers are removable from interior of tank with lifting of cover. Easy to clean.

330-gallon Lo-Vat equipped with two-piece insulation cover, new, quiet running-in-oil agitating drive, indicating thermometer and horizontal outlet flush valve.

The Pfaudler Lo-Vat type of glass lined pasteurizer, for the medium and small size dairy plant, has many new features which have made it the fastest selling pasteurizer on the market . . . some of the reasons:

1. Can be used with equally good results for pasteurizing milk or cream, for making, pasteurizing and ageing ice cream mix, etc.
2. Glass lined, easy to clean and you KNOW when it is clean. *Averts metallic odors.* Heats quickly and evenly without cooking product. Saves money.
3. Compared with ANY similar pasteurizer, the Pfaudler Lo-Vats are the greatest value on the market. **Three sizes—100, 200, 330 gallons. Free catalog on request.**

PFAUDLER LO-VATS

. . . choice of the trade . . .

THE PFAUDLER COMPANY, 1515 Gas & Electric Bldg. Rochester, N. Y.

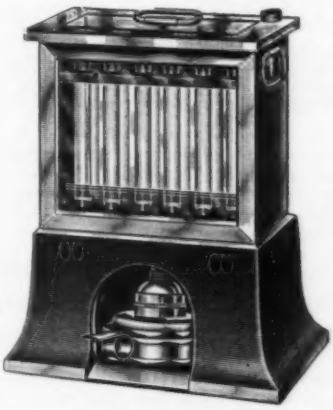
FUCOMA METHYLENE BLUE TESTER

FUCOMA METHYLENE BLUE TESTER

24 bottle tester compl. **$25.50**

36 bottle tester compl. **$29.50**

100 Tablets **$2.50**



THE FUCOMA REDUCTASE TESTER

is hand made of unexcelled workmanship. It is perfect in every detail. Many thousands in actual use in every part of the world.

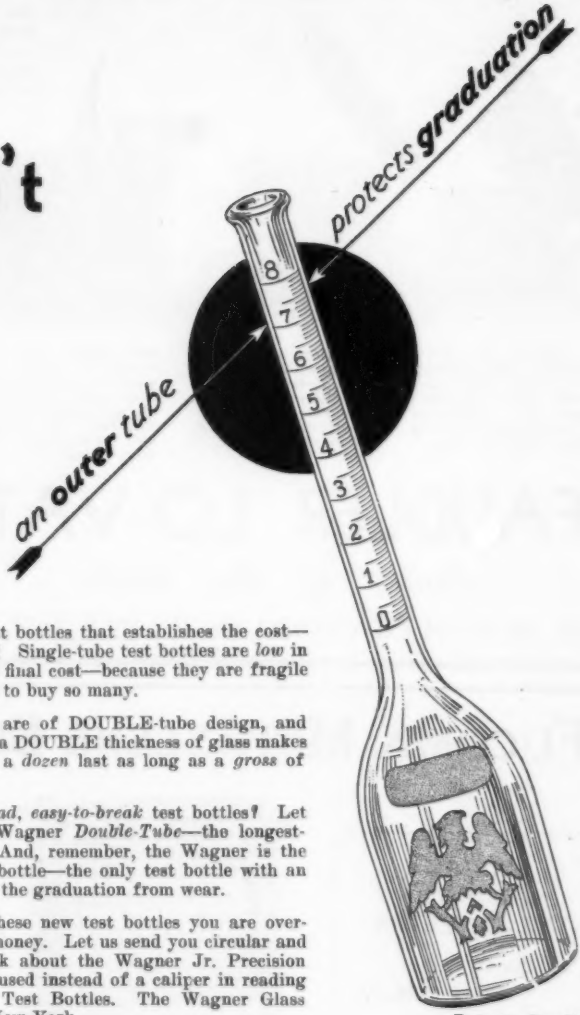
FUCOMA COMPANY INC.

Dairy Laboratory Supplies

216 WATER STREET **NEW YORK**

Your advertisement is being read in every State and in 25 Foreign Countries

NO —it doesn't cost any more



IT isn't the *initial* price of test bottles that establishes the cost—it's how long the bottles last! Single-tube test bottles are *low* in first cost, but they're *high* in final cost—because they are fragile and easy to break, and you have to buy so many.

The new Wagner Test Bottles are of DOUBLE-tube design, and that means DOUBLE strength—a DOUBLE thickness of glass makes them so sturdy and strong that a *dozen* last as long as a *gross* of ordinary test bottles!

Why continue to use *hard-to-read, easy-to-break* test bottles? Let your next supply be the new Wagner *Double-Tube*—the longest-lasting test bottle ever made. And, remember, the Wagner is the only *permanently-readable* test bottle—the only test bottle with an *outer glass sleeve* which protects the graduation from wear.

If you are not already using these new test bottles you are overlooking an opportunity to save money. Let us send you circular and quotations. And be sure to ask about the Wagner Jr. Precision Column-Meter, which should be used instead of a caliper in reading the new Wagner Double-Tube Test Bottles. The Wagner Glass Works, 695 East 132nd Street, New York.

Patents Pending

Distributed by:

CHERRY-BURRELL CORPORATION, 427 W. RANDOLPH ST., CHICAGO

Baltimore, Boston, Cedar Rapids, Cincinnati, Cleveland, Columbus, Detroit, Little Falls, Milwaukee, New York City, Pittsburgh, Philadelphia, St. Paul, Syracuse

THE CREAMERY PACKAGE MFG. CO., 1243 W. WASHINGTON BLVD., CHICAGO

Atlanta, Boston, Brooklyn, Buffalo, Denver, Kansas City, Los Angeles, Minneapolis, Omaha, Philadelphia, Portland, Ore., San Francisco, Seattle, Toledo, Waterloo, Ia.

WAGNER

Established 1887

MILK AND CREAM TEST BOTTLES

Your advertisement is being read in every State and in 25 Foreign Countries

Mojonnier
VACUUM PAN
Evaporates 7500 lbs. Water Hourly

Which?

Mojonnier
VACUUM PAN
100 lbs. Water Hourly

Whether you need a unit that will evaporate 7500 lbs. of water an hour, or only 100 lbs., there is a size Mojonnier Vacuum Pan of capacity best suited to your needs. The small 15″ diameter model is especially adapted to laboratory use in colleges and experimental stations.
Operates on the same principle and has the conveniences of the larger sizes. Write for details and prices.

Mojonnier Bros. Co.
MILK ENGINEERS
4601 W. Ohio St., Chicago, Ill.

MARSCHALL PRODUCTS
for cheesemaking

meet the most rigid requirements for purity, strength, and uniformity. Dependable results are assured the user of

Marschall Rennet Extract
Marschall Rennet Powder
Marschall Cheese Color
Marschall Testing Supplies
Marschall's D-S-D (*chlorine disinfectant*)

Samples and detailed information gladly furnished

MARSCHALL RENNET AND COLOR — AMERICA'S FAVORITE BRAND

Marschall Dairy Laboratory
Madison, Wisconsin
U. S. A.

INFLUENCE of Utensils on Milk Quality

TESTS made by Professor A. C. Berry, of the Board of Health, Province of Ontario, Canada, show the effects of unclean utensils upon the keeping qualities of milk. Milk was put into pails of different degrees of cleanliness, and allowed to stand at room temperature until it reached an acidity of 0.35, at which it was sour. The time it took each to reach 0.35 acidity was recorded. The tests show conclusively the great gain in quality of milk, by giving the utensils a final chlorinated rinse to sterilize them before use.

Test A—9 pails were washed and sterilized with a final chlorinated rinse. Average number of hours it took this milk to reach 0.35—68 hours.

Test B—9 pails were washed, but without the chlorinated rinse. Average number of hours it took this milk to reach 0.35—49 hours.

B-K, at the reduced prices, provides an economical, reliable and effective method of controlling bacterial infection from utensils and equipment.

New Low Price
B-K now $1.70 PER GAL. in 5 gal. bottles

$2.00 per gal. in 1 gal. bottles.

Quantity Prices Upon Request

General Laboratories, Inc.
729 Dickinson St. Madison, Wis.

Your advertisement is being read in every State and in 25 Foreign Countries

How *this* new operating principle

greatly increases the churning profits possible per pound of cream

The Model H Churn—now available in 1000 and 1500 lb. sizes—is entirely different from the ordinary churn. It churns more exhaustively; usually will hold fat losses below 0.1% in all seasons. This is made possible by a high drop and heavy concussion, 2 to 3 degrees colder churning temperature, and improved drum design.

It works the butter more thoroughly and still retains the dry, waxy body so necessary to premium grade, thanks to colder temperatures and the continued use of *two* positively driven rolls.

Salt and moisture are more thoroughly and uniformly worked in. Any good operator can quickly learn to hold moisture readings everywhere the same within 0.1 or 0.2 of one per cent.

With the composition and texture perfect, naturally there is no evidence of improper moisture distribution. Salt pin points rarely form. Moisture drops never form on the trier. And only a few extra ounces (2 or 3, some say) are needed per 63-lb. tub for butter to print out 100% after storage.

Naturally, Model H butter places high in sweet aroma and delicious flavor. The churn is easier to service and keep sweet smelling and sanitary, because fat doesn't impregnate the woodwork so easily at low temperatures.

Low costs are the result of improved mechanical construction, including such features as Timken bearings, alloy steel gears, enclosed-in-oil design, heavy castings, and other features which cut down operating, maintenance, and depreciation costs.

Full facts on the Model H Churns will be furnished on request to THE CREAMERY PACKAGE MFG. COMPANY, 1244 W. WASHINGTON BLVD., CHICAGO, ILLINOIS.

MODEL H^{10}_{15} CHURNS

The modern method *of butter making*

Your advertisement is being read in every State and in 25 Foreign Countries

The Ayrshire—

The Ultimate Dairy Cow

Assure the future *success* of your students and the farmers in your state by demonstrating the characteristics of the Ayrshire.

The breed that produces the greatest amount of 4 per cent milk at **lowest feed cost.**
The breed that makes **good** under any reasonable conditions.
The breed that produces the **ideal milk** for infant, nursery, and retail trade.
The breed that is **healthy, vigorous,** and **rugged.**
The breed with udders that stand **wear** and **tear** and are easiest to keep **clean** and **healthy.**

At your service

Ayrshire Breeders' Association

Brandon, Vermont

Back Numbers

JOURNAL OF DAIRY SCIENCE

Complete sets of volumes 2 to 14 inclusive are available, also many individual numbers and volumes.

"YOUR ONLY TRUE COMPETITION IS *BETTER QUALITY*"

Uncle Jake

IN the Dairy Industry the maintenance of quality is imperative — both for public good and private profit.

Many of its leaders find it easier to sustain a high standard of product when KVP scientists plan their wrappers.

KVP

GENUINE VEGETABLE PARCHMENT

—keeps products fresh for the longest possible time; promotes cleanliness and aids in establishing consumer identity.

Let us confer with you on your problems.

Kalamazoo Vegetable Parchment Co.
KALAMAZOO - MICHIGAN

Your advertisement is being read in every State and in 25 Foreign Countries

"Mr. Brown, there is a difference in Dairy glassware!"

It may not be apparent to the eye, but two pieces of dairy glassware of different manufacture can possess widely different characteristics. The dairy chemist knows this from daily practice. He knows, for example, that good appearance alone does not make a good Babcock Bottle — that unfailing accuracy, long service and true economy in test and control glassware depend upon its proper tempering — its exactness of calibration—its ease of reading — and its resistance to breakage.

Kimble Dairy Glassware has for many years held the front ranks in the industry. The fact that man and methods can fabricate no finer glass — that faultless construction and unquestionable reliability have placed it in daily use in the nation's leading dairy laboratories—makes it "America's Standard of Assured Accuracy."

Stocked by leading Dairy Supply Houses throughout the United States and Canada.

KIMBLE GLASS CO.
VINELAND, N. J.

BRANCH OFFICES:—New York, 1440 Broadway; Philadelphia, 1616 Walnut Street; Boston, 131 State St.; Chicago, 23 N. Desplaines St.; Detroit, General Motors Building.

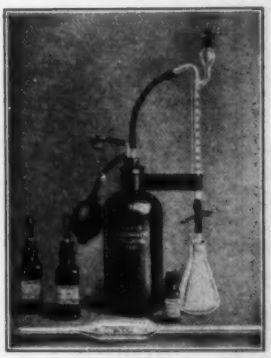
NAFIS
DEPENDABLE GLASSWARE

NAFIS AUTOMATIC CAUSTIC TEST

assures definite control of bottle and can washing solutions and tests the purity of washing powders. Practical test for machine operators. Shows per cent of Total Alkalinity, Free Caustic and Carbonates. NAFIS Faultless Stirring Rod contains color standards to match in test.

NAFIS AUTOMATIC CHLORINE TEST

determines amount of available chlorine in rinse waters used in bottle and can washers, vats, pipe lines, tank cars and other equipment. Also used for testing concentrated chlorine solutions. Automatic burette reads direct in parts per million.



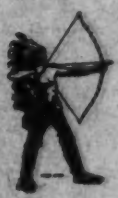
LOUIS F. NAFIS, INC.
23 N. Desplaines Street,
CHICAGO, ILL.

Your advertisement is being read in every State and in 25 Foreign Countries

You can *see* the Difference

You can actually *see* the difference between ordinary cleaning and the thorough cleanliness given by Wyandotte Cleaner and Cleanser. When cleaned with Wyandotte, cans, machinery, and equipment retain their bright, smooth, new appearance.

Wyandotte does not pit, discolor, or scratch metal surfaces. It gives you sanitary cleanliness with complete safety to the things it cleans.



Order from your Supply Man or write for detailed information.

Wyandotte
Dairyman's
Cleaner and Cleanser

The J. B. Ford Company

Wyandotte, Michigan

DIFCO

CULTURE MEDIA for DAIRIES

Bacto-Nutrient Agar

Bacto-Nutrient Agar is a complete medium which is readily prepared for use. Neither filtration of the solution nor adjustment of the reaction is required.

Bacto-Nutrient Agar is the standard medium for plate counts of milk. Its use is approved in "Standard Methods of Milk Analysis." Samples are submitted periodically to the Committee on Methods of the International Association of Dairy and Milk Inspectors for approval.

Bacto-Malt Agar

Bacto-Malt Agar is recommended for making mold and yeast counts of dairy products, particularly butter and cheese. It is easily made up for use in the laboratory.

Bacto-Malt Agar is recommended in the Reports on Standardization of Butter Examination of the American Dairy Science Association.

Specify "DIFCO"

THE TRADE NAME OF THE PIONEERS
In the research and development of Bacto-Peptone and Dehydrated Culture Media

DIFCO LABORATORIES
DETROIT, MICHIGAN, U. S. A.
Bacteriological Division of Digestive Ferments Co.

JOURNAL OF DAIRY SCIENCE

Official Organ of
American Dairy Science Association

Agents in Foreign Countries

For Argentina and Uruguay: Beutelspacher y Cia, Sarmiento 315, Buenos Aires.

For Australia: Angus & Robertson, Limited, 89–95 Castlereagh Street, Sydney; Stirling & Co., 317 Collins Street, Melbourne.

For Belgium: Henri Lamertin, 58 Rue Coudenberg, Bruxelles.

For the British Empire, except Australia and Canada: Baillière, Tindall & Cox, 8 Henrietta St., Covent Garden, W. C. 2, London.

For Canada: Wm. Dawson & Son, Ltd., 87 Queen Street East, Toronto.

For China: Commercial Press Ltd., Paoshan Road, Shanghai, China.

For Denmark: H. Hagerup's Boghandel, Gothersgade 30, Kjöbenhavn.

For France: Emile Bongault, 48 Rue des Ecoles, Paris.

For Germany: B. Westermann Co., Inc., Kranzenstrasse 38, Berlin NW 19, Germany.

For Holland: Scheltema & Holkema, Rokin 74–76, Amsterdam.

For Japan and Korea: Maruzen Company, Ltd. (Maruzen-Kabushiki-Kaisha), 11 to 16 Nihonbashi Tori-Sanchome, Tokyo; Fukuoka, Osaka, Kyoto, and Sendai, Japan.

For Spain: Ruiz Hermanos, Plaza de Santa Ana, 13, Madrid.

Subscription price is $5.50 per volume, postpaid, except in Canada and countries within the Postal Union where the price is $5.00.

The Science Press Printing Company,
Lancaster, Pa., U. S. A.